

ARROYO SECO

SCIENTIFIC AMERICAN SUPPLEMENT

Copyright 1917 by News & Co., Inc.

VOLUME LXXXIV
NUMBER 2185

★ NEW YORK, NOVEMBER 17, 1917 ★

[10 CENTS A COPY
\$5.00 A YEAR]



Press Illustration Service, Inc.

It is an anxious moment for the push-cart seller when an inspector starts to test his scales. If the weights have been tampered with—or are under the standard for any reason—they find an immediate grave in the river or handy sewer. The East Side women have learned that the inspector is there to protect them and are always interested in his doings

SAFEGUARDING THE PEOPLE'S FOOD—[See page 312]

Some High-Pressure Phenomena*

Latter Day Experiments that Have Thrown New Light on Physical Problems

THE older generation of the present day has had to learn a great deal since leaving college, and has had to unlearn a good deal as well. The indestructibility of the atom has gone, to be resuscitated in a new sense; the discredited emission theory of light has come to honor again; our notions of transparency have been revolutionized; one permanent gas after another has had to submit to liquefaction; and the incompressibility of liquids is no longer an orthodox tenet. When liquids and solids were exposed to pressures and temperatures of thousands of atmospheres and degrees, scientists recognized that their admitted ignorance of the nature of liquids and solids was greater and their knowledge far more defective and faulty than had been assumed. Materials had been too much judged by what they appear to be at ordinary temperatures. But the study of extreme conditions, low and high, promised to simplify our views. Life and complexity seemed, and seem, to be impossible under extreme conditions; many differences appeared to vanish as absolute zero or very high pressures were approached, and it looked as if the liquid molecule would become too closely packed at high pressure to admit of much variety, at any rate as to compressibility and thermal expansion. Those anticipations have not been realized. Liquids seem to retain their physical peculiarities at 20,000 atmospheres, and the assumptions concerning the processes going on in the interior of the earth remain as speculative as they were. One general conclusion may perhaps be drawn. On the whole, rise of temperature and rise of pressure have analogous effects. That temperature is the more powerful agent, apparently, and that a rise of 10 deg. may be said to correspond to a pressure rise of 1,000 atmospheres, is largely due to the selection of our units. It would also appear that, from the molecular standpoint, the liquid state is really intermediate between the gaseous and the solid states—in other words, that the gas laws cannot generally be extended to liquids.

Water was the first liquid systematically attacked. Water has many peculiarities. It was considered strange that water, almost alone of all substances, should have a maximum density at 4 deg. C. above its freezing-point and that it should expand in freezing. Then Tammann (Göttingen) found, twenty years ago, that there are three or four kinds of ice, not merely differing as to the system of crystallization, but strongly showing the peculiarities of distinct modifications, stable over different ranges. P. W. Bridgman (Harvard College, Cambridge, Mass.), extending the range of experiments, distinguished five kinds of ice, which he numbered I, II, III, V, VI (he does not accept Tammann's ice IV), possibly with subdivisions, and his equilibrium diagram water-ice is as complex as the iron-carbon diagram. Does water really stand alone? So far it seems so in some respects. But it is as yet too early to speak definitely.

Most solids expand fairly regularly, but not quite regularly, when heated; on melting there is a sudden large expansion (5.5 per cent in tin), and the heated liquid continues to expand. The cooled liquid contracts and freezes at the same temperature if pressure, etc., be the same. Many substances like quartz and phosphorus pass into different modifications when heated and compressed. All the characteristic points are influenced by pressure. At a pressure of one atmosphere ice melts at 0 deg. and mercury at -38.8 deg.; at 100 atmospheres ice melts at -1 deg. To melt mercury at 0 deg. the pressure has to be raised to 7,600 atmospheres, which may be called the melting pressure at that temperature. In the case of mercury and most substances the rises of temperature and pressure proceed on parallel lines; at 12,000 atmospheres the melting-point of mercury is +21.99 deg. C., and the Δt , the rise in the melting-point per 1,000 atmospheres, has throughout the range the almost constant value of about 5 deg. For this reason Bridgman was able to measure some of his pressures by the aid of the electric resistance of a mercury gauge. In the case of sodium the Δt diminishes for the same range, 0 to 12,000 atmospheres, from 16.2 deg. to 5.2 deg.; in the case of carbon dioxide—which melts at -56.6 deg. at 1 atmosphere and at +93.6 at 12,000 atmospheres—the Δt diminishes from 19.3 to 9.3 deg. (Bridgman).

All liquids and solids, we further find, are compressible, and the absence of some incompressible material naturally renders these investigations very difficult. Graphite, sometimes proposed as reference substance, A. L. Day and Soeman found—at the Geophysical Laboratory of the

Carnegie Institution, Washington, where John Johnston, presently to be mentioned, also works—occurs in several modifications. Tool steel seems to be the most suitable material. A pressure of 10,000 atmospheres reduces 1 volume of steel to 0.99, 1 of glass to 0.974. Different kinds of steel and iron had about the same compressibility of 5.3×10^{-3} , aluminium gave 11.7×10^{-3} , Jena glass 2.2×10^{-3} —all at 8,800 atmospheres. Bridgman further reduced the volumes of a dozen liquids, alcohols, ethers, acetone, carbon disulphide, etc., all to about 0.75, by pressures of 12,000 atmospheres. The curves of these liquids all looked regular, the rate of compression decreasing at higher pressures; but they all had their peculiarities, though nothing like those displayed by water; and there is no "normal" liquid. Compressed at 20 deg. C., water contracts to about 0.82 at 9,000 atmospheres; then the volume suddenly drops by 7.5 per cent of the original volume, after which there is a further steady but very slight compression. We have already stated that the equilibrium-diagram water-ice is very complex; the following melting-points (and corresponding pressures) will exemplify this:—8.8 deg. (1,000 atmospheres, ice No. I, see previous column); -22.0 deg. (2,115 atmospheres, triple point, at which ice I, III and liquid are all possible); -34.7 deg. (2,170 atmospheres, triple point, ice II); -24.3 deg. (3,510 atmospheres, triple point, ice III, V, II); -17 deg. (3,530 atmospheres, ice V, liquid); -4.2 deg. (5,500 atmospheres); +0.16 deg. (triple point, ice V, VI, liquid); +12.8 deg. (8,000 atmospheres); +73.6 deg. (20,000 atmospheres). Thus there are, according to Bridgman, five or six triple points, and ten or eleven transformation lines. Increasing pressure first lowers the melting-point, and then, above 2,115 atmospheres, raises it. All the ices, except I, are denser than water; ice VI is the most stable, and the only one possible above 0 deg. C.; hot water at +75 deg. would freeze to ice VI at 20,000 atmospheres. The changes are usually rapid at the triple points, but sometimes very slow.

But these features are not altogether singular. In the expectation that the properties of liquids would at low temperatures approximate to the characteristic properties of solids, W. Seitz and G. Lechner, of Aachen, in 1915 submitted some hydrocarbons, alcohols, ethers, etc., to low temperatures and high pressures, partly making use of experimental arrangements similar to those adopted by W. Wahl, of Helsingfors, in the researches which he conducted in the Davy-Faraday Laboratory.² In some cases Seitz found the coefficient of thermal expansion to diminish with falling temperature to a minimum at about -40 deg. C. for alcohols, and at -70 for carbon disulphide, to rise again afterwards. In other cases no minimum was reached at -120 deg. C. As the pressure was raised to 1,000 atmospheres the tendency of the coefficient of expansion to increase with falling temperature became more marked than at ordinary pressure. Wahl found that solid oxygen is dimorphous, and that methane and some alcohols crystallize in the cubical system; we should refer our readers to his researches. Bismuth, which, like water, expands in freezing, follows the analogy of water in so far as its freezing (or melting) point is lowered (not raised) from 271 deg. C. to 1 atmosphere, as the pressure is raised, to 218 deg. at 12,000 atmospheres; but the curve is quite regular. Heating white phosphorus to 200 deg. C. at 12,000 atmospheres, Bridgman observed a sudden condensation of the vapor, after a gradual fall of pressure, to a gray phosphorus of density 2.7 (against 1.9), which he could not prepare in any other way; this phosphorus resembled graphite and was a fair conductor of electricity. A. Smits obtained gray phosphorus in a different way; there is also a violet phosphorus, whilst the formerly assumed red phosphorus is not now regarded as a pure modification.

Whether or not increased high pressure will continue to raise the melting-point of a solid, or whether the curve will pass through a maximum, which would mean that, at sufficiently high pressure, all solids should liquefy, no matter what the temperature (Tammann), is not settled. Bridgman and Johnston argue that there is no reason for the latter assumption, nor for the analogous suggestion that there must be a critical end-point in the liquid-vapor curve. When saturated steam is super-heated in the presence of water the liquid and vapor phases become indistinguishable at the critical end-point of about 370 deg. at 200 atmospheres (365 deg. C. and 194.6 atmospheres according to Battelli). Below the critical point, but not above it, increased pressure will always condense part of the steam. But the water vapor or gas might directly condense to ice,

as the phosphorus does. In the case of carbon dioxide the critical temperature is +31 deg. when the pressure is 5,500 atmospheres. Beyond that temperature only gas and solid CO₂ seem possible, and the melting curve is quite regular and does not show any break or inflection at the critical temperature. These considerations are of high geophysical importance. From the absence of tidal motion within the interior of the earth and the rate of propagation of earthquake waves—which may describe an arc in the solid crust, or travel in a chord right through the interior—it seems to follow that the interior of the earth must be solid and cannot be liquid. But the subject is too obscure, and would be so even if the problems were merely physical, and if chemical reaction did not come into play. Minerals, so far as investigated, expand with fair regularity; in the case of rocks the phenomena are complex.

So far we have referred to uniform, purely hydrostatic pressure. Non-uniform pressure, of the nature of a shear, should affect solids only and not affect the cases mentioned, in which the specimens were placed within compression chambers filled with kerosene or gasoline—the viscosity of which increased enormously. But non-uniform pressure would enter into the phenomena of the liquids when there is a possibility of the presence of both a solid phase and a liquid phase; there might also be some unintended contact between solids in the experiments, or at any rate restriction in the free propagation of changes in the hydrostatic pressure. One can understand that uniform and non-uniform pressures may have different effects, and that the effects of a shear superposed upon a uniform pressure will be relatively very strong, especially when acting upon a small area. But it is difficult to see why—quite in general, as Johnston put it—uniform pressure should raise the melting-points and non-uniform pressure should lower them. Shear above the elastic limit results in a deformation from which the solid cannot recover. It requires some effort to imagine that uniform stress, sufficiently strong to produce an appreciable compression, can be altogether devoid of a shear, though the elastic theory makes that demand.

The effect on a melting-point or a transition point (at which one solid modification passes into another) of unknown extra stress, not hydrostatic, has received very meager attention, as Bridgman pointed out last year. In his own consideration, which he bases on Voigt's general thermodynamic potential of solids under stress, he suggests that two phases of a substance, initially in equilibrium with one another, are in contact across a membrane permeable to the reacting phases. That fictitious membrane, he admits, is a severe strain on the imagination, and his conclusion is not easy to understand either: "A solid subjected to any stress system whatever (tension, compression or shear) experiences a depression of the melting-point at the unstressed surface (or at a surface stressed by less than the average amount), and melting will take place at that surface if the stress be high enough." The statement is free from all hypothesis as to the nature of the contact between the crystalline grains. Plastic flow, he maintains, is produced under certain conditions by an actual melting with regelation of those crystalline grains which bear the brunt of the stress, this local melting being governed by the equations for an unequally-stressed solid, and not by the equations for a solid under hydrostatic pressure in equilibrium with a liquid not under pressure. This contributory agent in plasticity does not appear to Bridgman to be largely effective in the majority of practical cases, however, for many substances an analogous effect due to the displacement of polymorphic transition points would be of more importance.

Some thirty substances were examined by Bridgman as to polymorphic changes, alkali salts, organic compounds, etc., and two or three modifications were found in most of these cases, whilst a hundred other substances, did not show transition points. One might expect that the phase with the smaller volume would display the smaller compressibility and the smaller thermal expansion, and that the phase which is stable at higher temperature would have the higher specific heat. From this point of view, however, there were, in the several respects, as many normal substances perhaps as abnormal substances. The case of mercuric iodide (known in a yellow and a red modification) is interesting; the transition curve had a maximum at 4,800 atmospheres and 181 deg. C.

As regards electrical resistance Bridgman found that pressures up to 12,000 atmospheres reduced the resistance of 22 metals in all cases, except those of bismuth and antimony; this exceptional behavior of antimony was unexpected. The changes in resistance amounted to as

*Engineering.

¹Pressures are, for the present, understood to be purely hydrostatic, and are expressed in atmospheres, 1 atm. = 1 kg. per sq. cm.

²See Engineering, May 8, 1914, page 538.

much as 12 per cent in some cases, and the pressures applied would, with respect to compressibility, probably reduce the volumes of the metals in question to less than the volumes at absolute zero temperature. The temperature coefficients changed very little with pressure.

One can scarcely picture to oneself what should, from a common-sense point of view, take place at high compression. Too many factors enter, of similar and of opposing natures; the thermal factors—latent heats, specific heats, conduction, etc.—are complex in themselves. Pressure effects on chemical reactions—disregarding cases in which gases play a part—on solubility, electrolytic conductivity, etc., seem to be weak; as long as pressures of a few atmospheres only were tried, the effects were possibly underrated; later on they were overrated.

The question of purity becomes of the utmost importance at high pressures. A good deal of what is regarded as plasticity may be due to traces of impurity which will influence chemical reactions, the specific heat and local melting. For various reasons the surface layer of a substance is frequently considered as being distinct from the material underneath, and we do not know in how far the liquid medium in which a solid is being compressed might count as impurity. The high pressures of modern laboratories may be insignificant, moreover, compared to the pressures in the earth's crust, which raised continents and mountain ranges and folded and broke and actually turned topsy-turvy strata many hundreds of feet in thickness. They may be insignificant also compared with molecular forces. Yet they might release molecular forces which only come into play at close contact. Then the influence of the shape of the molecule and atom would exert itself, and if the atom be not an entirely homogeneous sphere, but something possessing a structure in which local centers of force will exist, the extreme complexity of compression and concomitant phenomena would appear less incomprehensible.

German Sources of Nitrates*

OWING to our neglect to develop the preparation of nitric acid by other methods, this country is dependent for it upon the import of nitrates from Chile, without which we should be almost powerless to cope with the present unprecedented demands for all forms of explosives. To the lay mind the ability of the Central Powers to continue the manufacture of explosives on an unheard of scale while the import of many of their essential raw materials is interrupted may seem something of a mystery; but the explanation is that German chemists, backed up with ample capital, have solved the problem for themselves, with the result that they will be in a position (so far as can be ascertained) to turn out some 350,000 tons of nitrogen during 1917, as compared with a pre-war consumption of about 200,000 tons. Before 1914 Germany imported from Chile about three-quarters of a million tons annually of saltpetre, or sodium nitrate, which accounted for more than half of her consumption of nitrogen. In addition to losing this product she has probably had to relinquish another source in the form of lime-nitrogen obtained from Norway, to the extent of about 40,000 tons per annum.

At the present time the methods available for recovering nitrogen in useful form as employed in Germany, apart from direct electrical processes for combining oxygen with atmospheric nitrogen, may be classified under three headings:—(1) The recovery of the element from coal; (2) the fixation of atmospheric nitrogen in the form of cyanamide; and (3) the synthetic production of ammonia effected by bringing about the union of hydrogen and nitrogen in the presence of a special catalytic agent.

RECOVERY FROM COAL

The amount of nitrogen recovered from coal is equal, approximately, to half the total production of Germany. In the main, of course, it is the immense gasworks and coke-oven establishments of the country which recover the nitrogen of the coal in the form of ammonia, while there is also a considerable yield from producer-gas plants operating on such systems as those of Mond and Kerpely. Ammonia as a source of nitrogen is a particularly useful product to Germany, in that it may be directly converted into sulphate of ammonia and employed as a fertilizer in lieu of the interrupted supplies of Chilean nitrate, or, with the aid of still another process developed by the German chemist, it may be directly oxidized to nitric acid and used in the manufacture of explosives. Some years ago Germany realized that the ammonia derived from the distillation of her coal would be inadequate to meet her future requirements, and, with an eye, no doubt, towards coming events, she carried out, through the agency of the famous Badische Anilin firm, exhaustive research into the possibility of

preparing ammonia synthetically by the union of the two elements nitrogen and hydrogen, the commercial manufacture of both of which gases she had already mastered.

The synthetic production of ammonia consists in bringing about the combination of hydrogen and nitrogen in the presence of a special catalyst. The chief difficulty experienced is the extremely small affinity which hydrogen possesses for nitrogen even at high temperature. However, the process has now reached a stage bordering on practical perfection, and consists in intermixing the two elements in the proportion of three volumes of hydrogen to one volume of nitrogen, the mixture being afterwards subjected to a pressure amounting to some 2,600 lbs. per square inch at a temperature approaching 550 deg. C. In this manner a volume of liquid ammonia amounting to less than one-tenth of the original volume of gas taken is yielded. The reaction is highly exothermic, and, accordingly, provides the whole of the heat necessary for the process. Dr. Haber, the inventor, has stated that osmium constitutes the most effective catalyst, but the rarity of this element precludes its adoption, hence such substances as uranium and manganese, mixed with a high proportion of iron, are generally employed. Tungsten has also been spoken of in this connection. The dangers associated with the process may be appreciated from the fact that it is necessary to instal the compression chambers within bomb-proof shelters, while special tell-tales and alarms are provided to indicate the slightest trace of oxygen, which is sufficient to cause violent explosion.

NITRIC ACID FROM AMMONIA

The problem of synthetic ammonia being solved, the next essential was a means of converting the ammonia into nitric acid, and today a good deal is heard of the Ostwald oxidizing process, by means of which nitric acid is produced from pure ammonia. Thus we have an example of one useful form of combined nitrogen being converted into another form, which, so far as the exigencies of war are concerned, is the more sought after of the two. The Ostwald process depends upon the action of a catalyst on a mixture of ammonia with oxygen, or ammonia with air and oxygen, nitric acid and water resulting. Scrupulous care is necessary in order to ensure that the ammonia is free from anything in the nature of impurities likely to cause "poisoning," to which the catalyst is extremely susceptible. Synthetic ammonia undoubtedly lends itself to the process and greater precautions are essential when employing ammonia that is derived from gasworks, coke-ovens, or producer-gas plants. Only quite recently, however, it has been demonstrated in America, where a small Ostwald plant is in operation, that coke-oven ammonia may be sufficiently cleansed to make its use possible, although the cost of the necessary purification is an item which must not be lost sight of.

The great advantage of the Ostwald process is its continuous nature; but against this must be set the comparatively low efficiency of conversion, which is said to be no more than 85 per cent. One authority, in fact, states that—war considerations apart—the new method can scarcely compete with the ordinary nitrate process or with that of the electric arc, for, owing to its low efficiency, the cost of producing nitric acid with raw materials at their present value would be approximately 2.73d. per lb. by the nitrate method, and 2.75 d. per lb. by the Ostwald method. The latter process, however, possesses undoubted merits, in that it requires but little power and a relatively small plant, while the exit gases are several times more concentrated than those from any arc furnace.

NITROGEN FROM CYANAMIDE

No fewer than seven European countries have now completed plants for the manufacture of ammonia from lime nitrogen, or, as it is more commonly called, calcium cyanamide. In times of peace it is, of course, intended that the ammonia produced in this manner shall be converted direct into ammonium sulphate, and employed for agricultural purposes; but in France considerable quantities of anhydrous ammonia have been produced, while in Germany ammonia from the same source has undoubtedly been earmarked to a great extent for use in Ostwald plants. In the latter country there is definite evidence of the erection of a number of cyanamide plants fully equipped with the necessary oxidizing apparatus; and, if rumor may be relied upon, sums of money running into millions of pounds have recently been expended upon multiplying factories for the purpose. It must be questioned, however, whether the newer German plants are entirely based on the cyanamide principle; for the Haber process presents many advantages over that operating with lime-nitrogen, and there would seem to be no particular object in giving preference to the cyanamide method. Germany must certainly have realized that

the future of her synthetic nitric acid lies in a combination of the processes of Haber and Ostwald.

CALCIUM CARBIDE

This supply of calcium cyanamide is dependent upon calcium carbide, a compound which was, until recent years, manufactured in comparatively small quantities. Where, however, sufficient power is available (and in the past abundance of water power has, not with entire justification, been heralded as a *sine qua non*) it is an easy matter to produce the carbide in an electric furnace capable of attaining a temperature of about 3,500 deg. C. It has been shown that if lime is mixed with carbon and heated in a crucible the resultant products will be calcium carbide and carbon monoxide. On the working scale lime or chalk is used, while the carbon is supplied in the form of anthracite; and although Norway is the home of the carbide industry the anthracite has usually been shipped from this country, and was in some instances before the war discharged *en route* at Hamburg to be washed, owing to the lamentable deficiency in washing facilities in this country.

The raw cyanamide as turned out of the electric furnace contains about 25 per cent of nitrogen, and to convert it into ammonia it is treated with soda and slaked lime. The mixture is then subjected to a temperature of about 160 deg. in the presence of steam, when ammonia is produced. The quantity of lime and soda ash added is comparatively small, amounting in all to only 5 per cent of the weight of the cyanamide. The reaction itself is highly exothermic; hence, once started it will generate sufficient heat for its own operation. A plant destined for America was interfered with by the outbreak of war, and the apparatus, which was to have been delivered by Germany, was commandeered for the purpose of adding to the existing units of that country. It is interesting to note that for the production of nitric acid in the Ostwald plant the ammonia yielded by cyanamide is so pure that no trouble is likely to result from the poisoning of the catalyst.

HOME SUPPLIES

In considering the cyanamide question, however, it is essential not to lose sight of the Haber system with which the world over, the future seems assured. But a word of warning may be uttered as regards attempts to instal any scientific process from the outlines given in German patent specifications. Often these specifications, with great ingenuity, are drawn up to mislead rather than to inform. For instance, for the synthetic ammonia process, as described by the inventor, the necessity for pure hydrogen is invariably emphasized, where as there is every ground for supposing that Haber himself employs only a 95 per cent product which, from the point of view of cost, is a very different matter.

Brittleness in Pure Iron

AN investigation of a brittle phase occurring in commercially pure iron was described before the Iron and Steel Institute by Mr. W. J. Brooke and Mr. F. F. Hunting.

The iron in question, which is made by the Shelton Iron, Steel, and Coal Company, of Stoke-on-Trent and has a purity of 99.84 per cent, shows a characteristic red shortness when subjected to mechanical treatment between certain limits of temperature, though at other temperatures it is extraordinarily ductile and malleable, and indeed when cold is noticeably similar to copper in respect of malleability. Heated to well above Ar₃ and allowed to cool it invariably becomes red-short on arriving at about 900 deg. C., though all signs of brittleness disappear when the temperature falls to about 800 deg. But when it is heated up to the temperature, 850 deg., at which the brittleness is most marked on the cooling-down curve, it gives no sign of the phenomenon.

Investigation of the microstructure indicated that the iron has the property of throwing out a solution between the Ar₃ and Ar₂ points a eutectoid composed probably of iron carbide, phosphide, and sulphide, with possible traces of manganese sulphide and ferrous oxide. In this zone these are thrown out from the ferrite grains to the boundaries, and as the crystal grains show at this point a tendency to increase in size, this swelling forces the eutectoid, as it were, into rivers which flow until several of them meet, forming a lake. Since these lakes occur very frequently at the junctions of the crystal grains, they naturally assume a triangular shape, which has been found the most prominent type. As the temperature falls the ferrite grains become smaller, the number of rivers or tributaries increases, the lakes are reduced in volume, and the ferrite redissolves the eutectoid until all trace of it in a separate existence disappears, the whole structure gaining the appearance of normal ferrite. The temperatures at which the eutectoid appears and disappears coincide so remarkably with the beginning and end of the brittle zone as observed in practice that the authors judge that herein lies the cause of the red-shortness.

*London Times Engineering Supplement.



A Garden Terrace Theater, constructed of concrete, at Yankton, S. D.

A Garden Terrace Theater On a College Campus

THE accompanying illustration shows the Garden Terrace Theater on the Yankton College Campus, a unique and beautiful open-air stage and amphitheater, built for college and community purposes by private local enterprise. The theater enclosure, which consists of hedge and garden wall, is 140 x 200 feet, and will seat 2,500 spectators within perfect view and hearing of the stage. The terrace, or stage proper is 30 x 50 feet, but on occasion the entire stage and part of the garden, an area 50 x 140 feet, may be used for a dramatic scene or pageant spectacle. The theater is provided with complete and permanent equipment for electric stage lighting and illumination. The seating provided is light folding chairs which are removed when not in use, leaving the seating area a beautiful sloping lawn.

There is a fountain at the rear of the stage forming one of the ornamental features, and there will be garden seats of concrete and other ornamental objects of sculpture to carry out the style of the formal Italian garden. From grading and construction as now completed and shown in the accompanying photograph only a partial idea can be had of the beauty of the Garden Terrace Theater. It is one of those things which are not at their best when "brand new." But the charm of it will grow from month to month and season to season, as the surface tint of the wall is softened and mellowed by time, and as the vines creep over it, and the enclosing hedge of lilac, and the trees and shrubbery and the flowers in season, and the sloping lawn and terrace, come to their proper growth.

The roof of this garden theater is the sky, its floor the green turf and its walls, except such as are of concrete, are the foliage of trees and growing things. This much is true, to be sure, of many another of the open-air theaters which have lately sprung into such wonderful favor in all parts of the country. But this one is different. There is no other like it in the United States, as the stage walls, balconies and pergolas are of concrete and stucco.

The Garden Terrace Theater is a community enterprise, but although located on the college campus, and originated at the college under the department of English, in connection with its teaching of drama, it is not for the college alone, and not a penny of its cost has been drawn from college funds. It has been financed by a group of men who trust for the return of their outlay to proceeds from entertainments given, but will never receive any personal profit. In case profit

arrives in future it will be devoted to the development of the theater itself. This beautiful open-air stage and auditorium will be used for various college affairs, but for community purposes no less. It is intended as a civic center, a means of artistic and educational inspiration for the whole community and region.

The idea and design of this permanent open-air theater are original, yet absolutely sound in conception, from both the practical and artistic standpoints. The practical features of its construction were developed out of the experience of the past eight years of the college in presenting a Shakespeare play out-of-doors at commencement time. Those features, particularly the structure of the stage, were based upon the stage of Shakespeare's time in London, having two rear entrances and a stage balcony, but without curtain or wings and with a minimum of movable properties.

Extended study and practice at the college have demonstrated the adaptability and charm of such a stage for open-air plays, and for some years past the purpose has been forming in mind of providing, in place of temporary platform, rear screen, and other make-shifts, a complete and permanent equipment with artistic landscape and architectural setting for these out-of-door performances. It was believed, furthermore, that a permanent open-air theater of that kind could be used not only for the college Shakespeare play once a year, but for other other high class entertainments of various kinds, plays, pageants, concerts, etc., through the open season of spring, summer and fall. It was this purpose which gradually crystallized into the plan of the Garden Terrace Theater which is now in process of construction.

The design is essentially an Italian garden, inclosed by formal hedge and garden wall, with a terrace for the stage and a sloping lawn for seating the audience. To be sure the Italian garden, with its characteristic wall architecture, sculptural ornament and formal landscape, is not unknown in this country. It has become a feature here and there in fine city parks and wealthy private estates. But the adapting of the Italian garden to theatrical purposes, with stage and seating area, is the thing that is original with Yankton College. And yet this very idea is not an absolute novelty, but a revival, for it is taken directly from some of the beautiful old villa gardens of Italy, built centuries ago.

It was a custom, in the times when those world-famous gardens were laid out, to include in the design of the grounds a private garden theater, with a terrace for the stage and suitable seating place for spectators. There the nobleman would entertain his guests by a play performed by amateurs of his household or by companies

of traveling actors. Those old garden theaters of Italy are known to tourists and to landscape architects, but no modern adaption of them for theatrical purposes, so far as diligent study of the subject has been able to discover, was ever made until this present enterprise at Yankton. Practically the only modern publication of plans and pictures of the old garden theaters in Italy has been made very recently, subsequent in fact to the starting of work on the Yankton Garden Terrace Theater.

The detail plans for the Yankton garden theater were prepared by Mr. Phelps Wyman of Minneapolis, the man who has drawn the preliminary sketches for the proposed park system of Yankton and who laid out the state capital grounds at Pierre; and the wall architecture was by A. R. Van Dyke of Minneapolis, a specialist in that particular field of design. These architects, both of whom were enthusiastic over this unique project, gave to the subject very particular study and worked in collaboration to produce the design which was finally adopted. In order to secure the utmost possible assurance of the practical feasibility and artistic propriety of the garden terrace theater, the architect's plans were gone over in conference with a number of leading authorities on dramatic art and open-air entertainments in the United States. Among these were Mr. Charles D. Coburn of New York, head of the Coburn Players, Prof. George F. Baker of Harvard University, whose work in the teaching of practical drama and in conducting of open air performances is so widely known, Mr. Samuel Hume of the University of California, one of the originators and chief promoters of the famous Greek theater at Berkley and Prof. Fransworth, head of the musical department of Columbia University.

It is stated that Mr. Theodore J. Keene of the Art Institute of Chicago, who was director of a great pageant in Minneapolis, Prof. Clapp of the department of English at Lake Forest, and certain dramatic authors of successful experience have studied the design, working out scene by scene the staging of plays with reference to it. The important question of the acoustic properties of the Garden Terrace Theater was considered with care and approved by Prof. Sabine of Harvard University, known to be the principal authority on open-air acoustics in this country. These advisers, and others who have been consulted, without exception, have not only given their approval of the design in all its features, but have expressed admiration and enthusiastic interest in the Yankton project and believe that this new style of an open-air theater is destined to exercise distinct influence upon the rapidly growing movement in open-air dramatics and pageantry.

Annatto of Commerce

By C. D. Mell

BRASIL and French Guiana have always been the world's leading countries in the production and sale of annatto. Although this industry has declined to a fraction of its former output, these two countries still export to the United States and Europe more than \$500,000 worth of this vegetable dye every year. France has always been a large user of this product and so has Holland and England. About 800,000 pounds are consumed annually in the United States. This important tropical product is the roucou of the French dyers. The original Indian name was urucu, which the French corrupted to roucou. The English name is annatto or arnatto, but its local name in the tropics is achiote, though it is also sometimes referred to as bija.

This dyeing product was unknown to Europeans until after the discovery of America, being a native of tropical America only. The early settlers in the West Indies soon discovered its great value as a coloring substance and the small tree producing these useful color-yielding seeds was soon cultivated outside of its natural range of growth. It was introduced into the East Indies very early by the Dutch traders, where the tree found very congenial soil and climatic conditions and became so thoroughly naturalized that a number of the early European botanists traveling in the East, thought that the plant was a native of India and Java. It is said to grow now in practically all localities in which the orange tree thrives.

The annatto plant is a small, ornamental tree or shrub rarely attaining a height of more than 12 feet. It has an open, flat-topped crown with serrated, dark-green and beautiful leaves. The fruit is a prickly, heart-shaped pod of about an inch in length consisting of two valves. When the pods are ripe they are of a brownish-mahogany color, which open up lengthwise through the middle, exhibiting a number of seeds that are attached to a central placenta. The seeds which constitute the commercial product of this tree are quite small, of about the size and shape of grape seeds and are covered with a soft, slightly sticky vermilion-colored rind or pulp. It is this thin outer coating of the seed that contains the coloring matter. It requires fully eight months for the pods and seeds to mature, when they are collected and spread out in the sun for several days until they are thoroughly dry and have opened up. The pods are then beaten and thrashed with a form of flails or clubs for the purpose of separating the seeds from the placenta, after which the pods are separated from the seeds by means of sieves and fans. The pulpy matter is then removed from the seeds by maceration and washing and allowed to precipitate. After the water is poured off

the reddish or orange-colored cellular substance is dried and pressed into cakes, in which form it often comes into the market. This is the most important kind and is furnished almost entirely by Ceyenne. It was originally shipped into the markets in square cakes weighing from two to three pounds and wrapped in banana leaves. The good quality cakes yielded a bright yellow color, soft to the touch and of good consistence. Annatto also comes into the market in the form of rolls, chiefly from Brasil. These rolls are quite small rarely weighing more than three ounces. They are hard, dry, compact, brownish on the outside and of a beautiful red within.

The introduction of annatto seeds or cakes dates back several hundred years, and the amounts and values have always fluctuated. The uses have varied also a great deal. It was employed by the Caribbean Indians for painting their bodies, which first brought the dyeing qualities to the attention of the early explorers. It soon developed into an article of trade, and was at one time used in the dyeing of cotton and silk, but later it came into general use for staining cheese, butter, milk, candies, soap and varnishes. Annatto is being used extensively in American and European dairies, taking about an ounce to 100 pounds of cheese or butter. When annatto is genuine and pure it affects neither the taste nor the smell of cheese and butter. In Spain annatto is mixed with chocolate which imparts a beautiful tint. It is supposed to have medicinal virtues and is employed in the tropics as a purgative taken internally. It was believed also at one time that it acted as an antidote against the poison in cassava.

Of late years the use of annatto has declined, and it seems not improbable that before many years have passed that a still larger part of this once flourishing industry will be abandoned. This is due mainly to the competition of cheaper synthetic dyes. For a few minor

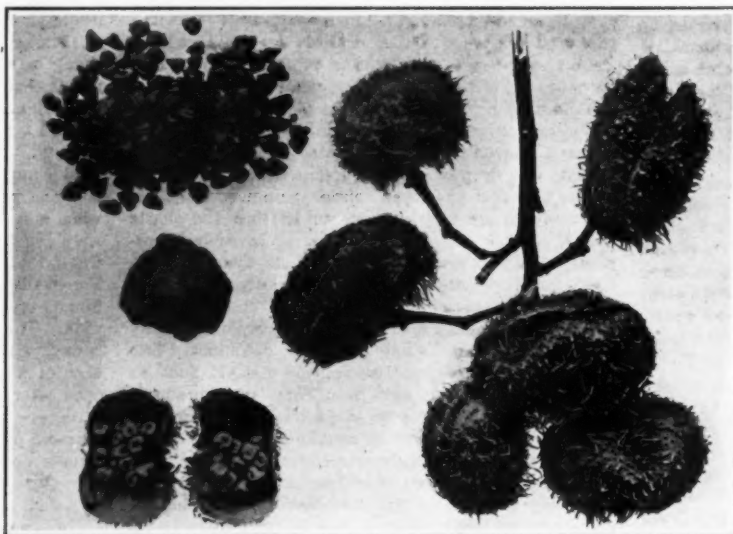
uses no satisfactory substitute has yet been discovered. The yellow coloring principle gained notoriety very early for tinting butter and cheese and it is more than likely that dairies will continue to requisition annatto dyes for this purpose.

The production of annatto is in many respects unique. While the tree grows wild the best results may be obtained from those under cultivation. Plantations are usually started by simply placing cuttings in the ground



A small annatto tree, showing numerous pods

at any time during the rainy season. It is said that plants produced from seeds flower less freely and do not bear fruit as soon as those obtained from cuttings. Propagation by cuttings is always advisable if one desires to grow and maintain a special variety, of which there are a number under cultivation. The distance the trees should be planted apart is dependent upon local conditions. As a general rule, a distance of from 12 to 16 feet is followed. While the tree is best adapted for growth in rich, loamy soil with plenty of moisture, it will grow successfully in almost any soil that contains sufficient moisture. Annatto is known to have produced good results where the soil had become exhausted



Pods and seeds of the annatto (natural size) also a small lump of dried annatto pulp

by growing coffee. There is very little work in connection with this crop and it is well suited for all hot countries where labor is scarce and inefficient. The only cultivation necessary is to keep down the growth of high weeds and to remove old and decrepit trees. If thinning is neglected the plants are apt to crowd each other which reduces the yield. A crop of seeds may be expected three years after planting, and in full bearing trees should yield from 16 to 48 pounds of pods and from 2 to 6 pounds of seeds, which bring about 17 cents per pound.

Phosphorescent Zinc Sulphide

COMMENTING quite recently upon investigations of the behavior of radium luminous compounds, we remarked that it would be of great advantage if the

luminosity of the zinc sulphide, in which the radium of luminous compounds is embedded, could be systematically studied in the first instance. There is quite an extensive literature on the phosphorescence of zinc sulphide, but not much agreement even as to the main facts. The latest contribution to these studies, published in the August issue of the *Transactions of the Chemical Society*, clearly brings out one of the reasons to account for contradictory statements and positively helps us on in other ways. Most of the various investigators did not sufficiently define the exact conditions under which they worked, and those conditions, especially of temperature, it is shown, are very important factors. The new research has been conducted at the University of Glasgow by Miss Elizabeth MacDougall and Messrs. Alfred W. Stewart and Robert Wright. Pure zinc sulphide, precipitated from zinc chloride or some other salt by ammonium sulphide, they find, shows no trace of phosphorescence—that was generally believed—but acquires it by being heated. Volatilized sulphide prepared by fusing zinc and sulphur in a crucible did phosphoresce, but the reactions did not admit of proper control; the experimenters returned to precipitation, therefore. Certain impurities of zinc sulphide have been considered to favor phosphorescence, others to prevent it. The experimenters introduced impurities, in traces or considerable percentages, mechanically or chemically, the latter either by working with salt mixtures, or by not washing the precipitate and by using an excess of the one or other reagent. They heated the precipitate to different temperatures for various periods, and obtained the best phosphorescence by heating to from 650 deg. to 900 deg. C. for 1½ hours; higher temperatures proved injurious; the resulting semi-crystalline product phosphoresced better than the amorphous or the crystallized; when the temperature was kept near 650 deg. the phosphorescence was blue, at higher temperatures green or yellow. Metallic impurities little affected the tint of the luminescence, except that manganese turned it into a golden-orange; this sulphide also showed an intense triboluminescence. The excitation of the phosphorescence requires exposure to light; magnesium, X-rays, cathode and Becquerel rays were tried. The first impact of cathode rays gave rise to a real flash of light; under continued exposure the whitish sulphide turned grey or brown, and the tint of the luminescence changed. Many impurities increased the phosphorescence of the pure sulphide. The presence of a chloride—which might lead to a secondary formation of zinc chloride—decidedly favored it, iron prevented it. Washing, grinding or rubbing the sulphide diminished the phosphorescence. When cooled in liquid air the sulphide stored up light energy, and it may be said generally that the sulphide is in some way

able to act as a reservoir for energy, which it can emit in particular light vibrations. The colder the sulphide, the more energy it can absorb, but the radiations must be of short wave-length. The physical condition of the sulphide is important and since grinding and washing diminish the phosphorescence, the impurity which favors the phenomenon may form a surface film. The significant impurity, the experimenters conclude, is probably the chloride ion. This conclusion is not very convincing, and we are sorry not to have any definite statement that the research will be continued.—*Engineering*.

Standard Highway Bridges

STANDARD bridge designs for Ontario have been prepared by the Provincial Highways Department as suggestions to counties and townships of what meets the Government requirements. The plans are drawn for spans varying by 2 feet up to 90 feet. Above that the spans are 100 feet and 120 feet. The loading is in all cases known as class "A," which provides for a 15-ton road roller. A bridge of this type is suitable for main traveled or country roads, and is recommended as the standard on all roads. The types of bridges indicated in the standard plans are rolled beams for spans up to 40 feet, pony Warren truss for spans of from 40 to 90 feet, and the through Pratt truss for the longer spans from 100 to 120 feet. These designs are prepared in accordance with the 1917 specifications for steel highway bridges as issued by the department. According to the *Contract Record*, all the bridges are designed to carry a dead load composed of the weight of the bridge and of a concrete floor 6½ inches in thickness in the center and 5½ inches in thickness at the sides, and a live load composed of a 15-ton road roller. End floor beams are recommended. Standard designs are being prepared for concrete bridges.

Sands for Glass Making*

With Especial Reference to Optical Glass

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Of the manifold uses to which sand is put none is more important than that for the making of glass. In spite of this fact, most glass manufacturers, like others interested in industries where suitable sand is essential, have done little or nothing towards investigating the reasons for the suitability or otherwise of the sandy materials they use. Economic geologists are equally culpable in not having investigated the resources and characters of the abundant and varied sands, and also related deposits, of this country.

The term "sand" in its popular sense includes many mixed products which are ruled out in the more restricted geological use of the word. The geologist understands by sand an incoherent rock made up of individual mineral grains with a limited range of chemical and mineral composition, but most importantly, having the majority of its grains, which are usually somewhat rounded, lying between certain size-limits. The mean diameter of the grains of a true sand does not rise above 2 mm., or fall below $\frac{1}{16}$ mm. Thus a "very coarse sand" has a high percentage by weight (ideally in each case, 100 per cent) of grains of diameter 2 mm. to 1 mm., a "coarse sand" of diameter 1 mm. to $\frac{1}{2}$ mm., a "medium sand" of diameter $\frac{1}{2}$ mm. to $\frac{1}{4}$ mm., a "fine sand" of diameter $\frac{1}{4}$ mm. to $\frac{1}{8}$ mm., and a "superfine sand" of diameter $\frac{1}{8}$ to $\frac{1}{16}$ mm. Each of these size-limits is known as a "grade," and the separation of a deposit into its constituent grades is known as "grading."

Commercially the term "sand" includes materials of varying grades (as for example, molding "sands") and differing composition; it is also applied to the products obtained by crushing consolidated sandstones and quartzites.

Most sands consist largely of silica occurring as broken fragments of the mineral quartz. The impurities present may consist of grains of other minerals, chemical substances tending to coat and cement the grains together, or as dust, etc., mixed with the deposit.

SANDS FOR GLASS-MAKING

Importance of sands in the process.—The choice of a suitable sand for use in the making of glass, particularly such special glasses as those for optical purposes, is an important question. Upon the quality or purity of the sand depend the transparency, brilliancy, luster, and hardness, of the glass, while its uniform density is determined to no small extent by the mechanical composition of the sand. Due regard must be paid to obtaining and treating suitably the sand in order that the "life" and "water-whiteness" of the best glass may be obtained. For optical glass and best "crystal" only the purest sands can be used.

In the matter of bulk also, the sand is the most important ingredient, constituting 52 to 65 per cent by weight of the "batch," or mixture of raw materials. The finished product, glass, contains 60 to 75 per cent of silica, the increase in proportion being due sometimes to the fact that silica is added as feldspar to the batch, but usually owing to the loss of gases, such as water, carbon dioxide, sulphur dioxide, etc., during the melting process.

Nature of sands.—Sands have been produced by the natural breaking down of the rocks which build up the earth's crust. The geological agencies of heat and cold, frost, and rain, are concerned in this gradual shattering of the rocks by chemical and mechanical means. Running water and gravity are continually at work moving the disintegrated material down to lower levels, and eventually to the sea.

The less stable minerals of the rocks decompose and are broken down into soluble salts and fine-grained insoluble residues, while the obstinate ones, such as quartz, are loosened from one another. Material of very mixed chemical, mineral, and grade composition, is thus produced, but the sorting action of wind and water soon comes into play. This sorting is controlled by the size and weight of the mineral fragments, the larger and heavier grains soon being dropped, while the fine clayey material is often carried for long distances. While the grading and the sorting of minerals according to density is never perfect, a strong tendency always exists towards simplification. The sediment, in time, comes to consist almost entirely of one mineral and of equal-sized grains.

From the point of view of the production of sands suitable for glass-making, the last factor is an extremely important one. Considering purity from the standpoint of silica percentage, pure sands are not common in occurrence, nor abundant when found. Great variation occurs in the mechanical (or grade) composition of sediments, and well-graded sands are by no means so frequently met with as we might expect. It is an interesting fact that all the best glass-sands, i. e., the purest and best-graded deposits, occur comparatively late in the geological time-scale.

The minerals composing sands may be divided into two groups, the allogenic minerals, derived from older rocks, and the authigenic minerals, which were formed at the time the rocks were deposited or subsequently. We are mainly concerned with the allogenic minerals. Some of the heavy detrital minerals are fixed chemical compounds, others are molecular mixtures which vary somewhat in their composition. Among the latter are such silicates as the pyroxenes, amphiboles, olivines, epidotes, etc.

Methods of investigation.—For the complete understanding of the characters and properties, and hence the economic uses and value of unconsolidated sediments, we need to know the chemical, mechanical, and mineral composition, and the corresponding three analyses of each sample.

Chemical analyses are carried out by methods familiar to all, the usual procedure in dealing with rocks being followed. Mineral analyses are made in detail by treating the sediment with heavy liquids of densities ranging from 2.56 to 3.3. The minerals such as quartz and feldspar which usually constitute 98 per cent or more of a sand, have a density below 2.8 while the iron oxides, ferro-magnesian minerals such as biotite mica, hornblende, augite, epidote, garnets, staurolite, and other heavy minerals (aluminous silicates such as muscovite mica, and alusite, kyanite, sillimanite, topaz, etc., and also zircon, rutile, etc.) have a density greater than 2.8. Bromoform, mercury potassium iodide solution, cadmium borotungstate solution, and other liquids of density about 2.8, are therefore employed to separate off the heavy crop of minerals which sink in them, from the lighter and much bulkier crop of quartz, etc., which floats. The crop of density, 2.8, usually does not reach over 1 per cent by weight, but it may range from 0.01 to 4 or 5 per cent. Other methods are employed, including microscopic examination, for the separation and investigation of the individual mineral grains.¹

Examination of a glass-sand under the microscope is easily carried out and yields interesting information. A small quantity of the sand may be mounted temporarily in a drop of clove oil upon a glass slip. Owing to the fact that the mean refractive indices of quartz and clove oil are very close to one another, the quartz grains, if they are clean, are almost invisible in ordinary light. A very thin pellicle of clayey or ferruginous matter upon them renders them easily visible, and the extent of ironstaining is thus quickly observed. Feldspar, when fresh, and unaltered, is similarly only faintly outlined, but when "kaolionised," i. e., decomposed into micaceous and clayey matter, appears dusky. Such an excellent glass-sand as that from Fontainebleau almost disappears on immersion in clove oil. Heavy detrital grains, when they do occur, usually stand out in bold relief, owing to their higher refractive indices.

The mechanical analysis is carried out with a view to finding the sizes of the constituent grains, and the percentage by weight of each grade.

The oldest and roughest method of making mechanical separations is the well-known one of sifting. The method is, however, inaccurate for scientific work, and if carried out at all, separations should be made with brass or copper sieves having punched round holes of diameter 2 mm., 1 mm. and $\frac{1}{2}$ mm. Below $\frac{1}{2}$ mm. punched holes are not practicable, and squared-holed wire-mesh screens must be used. In all cases it is the mean diameter of the sand-grains which determines what passes the sieves, but in the square mesh sieves the grading is less accurate owing to the greater length of the diagonal of the aperture. Sifting is thus not to be recommended below $\frac{1}{4}$ mm.; separation of smaller grades may be made to a fair degree of accuracy by the

use of elutriation. For detailed descriptions of the processes of elutriation in air or water, and the various forms of apparatus devised, reference must be made to the works cited.² Briefly put, elutriation depends upon the power of upward currents of air or water of varying velocities to buoy up grains of minerals of different surface areas. It has been found as a result of both calculation and experiment that the final velocity acquired by a small fragment of solid, approximately spherical, when falling freely in a fluid, such as water, depends primarily upon its surface area (and, therefore, upon its mean diameter) and to a less extent upon its density. Subsidence methods have thus been used (and are used in industry today, e.g., in the preparation of china-clay) to separate sediments into various grades. Such methods are not scientifically accurate, hence the adoption of elutriation, where upward currents of fluid are utilized, equal to or just in excess of the respective falling velocities of the particles of definite grade sizes which it is desired to separate. Water is generally used, and an elutriator consists essentially of one or more cylindrical vessels of known area of cross-section. The velocity of the upward current of water passing through is controlled by the head of water outside (often adjustable) the diameter of the vessels, and the size of the outlet jet. Usually a manometer-tube is attached to the elutriating cylinder to register the pressure and thus indicate the velocity.

A weighed quantity of sediment is placed in the cylindrical vessel, and by the variation in the velocity of the water-current, grading is effected, the respectively smaller grades being carried over, collected, dried and weighed. The various grades are calculated to percentage weights and the results may be expressed graphically.

The apparatus is easily constructed, being made of glass, and should find a place in the laboratory of every glassworks.

DESIDERATA OF GLASS-SANDS

Chemical Composition.—The chemical analysis of a glass-sand should indicate the percentage of silica (SiO_2), alumina (Al_2O_3), iron oxide (expressed as Fe_2O_3), and loss on ignition (H_2O , etc.). It is desirable in sands generally to have a full analysis, but those proposed for use in glass-making should bear little more than a trace of alkalis, lime, magnesia, etc. The silica percentage should be very high, preferably over 98 per cent, which means that the sand must be a pure quartzose deposit. For common bottle-glass the percentage may drop to 95, and for the best quality glass such as that known as "crystal," used for table-ware, and optical glass, the sand should possess 99.5 per cent or more of silica. Alumina is sometimes desirable in a sand, particularly when it is to be used for the manufacture of refractory ware such as thermometer-glass. Hovestadt mentions³ that thermometer-glass made in the Thuringian Forest district owes its special quality to certain sand found only in the neighborhood of the village of Martinsroda. The glass stands repeated melting, blowing and fusing, without change, while ordinary glass, such as that of windows, becomes rough and dull of surface even after short exposure to the flame. The cause of excellence is believed to be due to the 3.66 per cent of alumina present. In sands free from iron the alumina usually occurs as the mineral feldspar. Its presence as clay (hydrated aluminium silicate), either free or as a dust coating quartz-grains, is highly undesirable.

Unfortunately, alumina in a sand usually carries with it other impurities, especially iron and lime, so that it is advisable to use a pure quartzose sand for glass-making and to add the alumina required as such to the batch which is melted up to make glass.

Iron compounds are undesirable in a glass-sand, whether they occur as hematite and limonite coating the quartz, or as detrital mineral grains of magnetite, titaniferite, or the ferromagnesian minerals enumerated above. The effect is to give the glass a pale-green or

¹Schoene, E. "Ueber Schlemmanalyse." Berlin, 1876.
Kellbach, K. "Lehrbuch der praktischen Geologie." Leipzig, 4th ed., 1908.

²Crook, T. Proc. Roy. Dublin Soc. (Econ) Vol. I.; pt. 5 (1904), p. 287, and op. cit., p. 349.

³Stadler, H. "Grading Analyses by Elutriation." Trans. Inst. Mining and Metall. XX, 1912-13, p. 688.

⁴"Jena Glass," translated by J. D. & A. Everett. MM. & Co., London, p. 21.

*Abstracts from a paper read before the Optical Society (London) and published in the Transactions of the Society.

yellow color. By the addition of decolorizers such as manganese dioxide, arsenious oxide, etc., a certain amount of correction may be obtained, and glass practically white or with an exceedingly faint pink tinge be yielded. For the best glass, including optical glass, the iron percentage (estimated as Fe_2O_3) should not exceed 0.05 per cent, but for window and plate-glass, chemical apparatus, globes, etc., 0.1 to 0.2 or even 0.3 per cent may be permitted. Correction for iron by means of decolorizers is inadvisable in the case of optical glass on account of the absorption of light owing to the neutral tint produced.

Sands containing over 99 per cent of silica and less than 1 per cent of iron and alumina rarely carry more than a trace of lime, magnesia, titanium, potash, soda, etc. Sands containing any quantities of these compounds are not suitable for glass-making.

Mineral composition.—Just in the same way as valuable mineral products, such as gold, tin, and gems, are concentrated by natural agencies in stream-sands as a result of their high density, and are further concentrated by panning at the hands of the prospector, so the heavy detrital minerals of a sand may vary in proportion to the lighter quartz and feldspar, according to the conditions of deposition. Proximity to the source of the heavy minerals, and oscillatory current-action after or during depositions, tend to increase the amount. Taking an average for British sands and sandstones of all geological ages, the percentage weight of mineral grains of density greater than 2.8 is probably about 0.5. In certain very pure sands, sandstones and quartzites, it falls as low as 0.01 per cent; occasionally it rises in other deposits to 4 or 5 per cent. If a sand is used for glass-making, the percentage of heavy minerals should be low, since iron oxides and ferromagnesian silicates constitute a large proportion of the dense minerals present.

It is now possible to recognize many sands both as regards geological age and locality, from their heavy mineral assemblages. A considerable number of minerals, with much variety of form, size, color, inclusions and degree of alterations, in their grains, may be met with in these assemblages, and detailed examination will in most cases serve to indicate whether successive consignments of a sand come from the same bed or pit. Glass-manufacturers, in using the methods of mineral analysis, have in their hands a valuable check on such foreign deposits as Belgian and Dutch sands.

Mechanical composition.—A perfectly-graded ideal sand would have all its grains of closely the same size, that is, 100 per cent by weight lie between two close limits of size (as defined in the second paragraph of this paper).

No natural sands are perfectly graded, but those which most nearly approach the ideal are shore-sands and dune-sands which have been continually winnowed by wind and washed by water. Smaller grains have all been carried far away, and larger ones left behind when the deposits themselves have traveled along the shore.

By subjecting the sands which have proved most successful in glass-making (as well as those which have not) to mechanical analysis, it has been found that the grade is an exceedingly important factor. A few glass-manufacturers who have studied the technique of their work have realized this and placed the question of size of grain on an equality with that of chemical composition. Nevertheless, no systematic work seems to have been done, but it is to be hoped by now that elutriators have been set up in the laboratories of a few glass-works.

In order that the batch containing the sand, alkalies, and other compounds may melt freely, evenly, and as rapidly as possible, at least 70 per cent of the sand should be of one grade, preferably medium sand of diameter $\frac{1}{4}$ to $\frac{1}{2}$ mm. The practice in the United States glass industry appears to consist in the use of graded deposits of rather coarser grain than in this country. The presence of coarser fragments than the average in a glass-sand results in these being left unmelted as "stones" while the rest of the batch has become molten "metal." If heating is continued until the "stones" are also dissolved some glasses are spoiled by the chemical changes which take place, and the fresh gases which are evolved.

Finer material belonging to the clay grade (diameter less than 0.01 mm.) or silt grade (diameter between 0.01 and 0.05 or possibly 0.1 mm.), whether occurring as thin pellicles on the larger quartz grains, or acting as a bind, is inimical from the glass-making point of view. Clayey material, especially if it is such a pure clay as kaolin or china-clay, is refractory, and clouds the glass. Fine particles also carry with them air-bubbles, from which it is very difficult to clear the metal. If the batch is melted in pot-furnaces, the finer quartzose material (superfine sand, silt, etc.) tends to melt first and sink to the bottom. Subsequent melting of the rest of the batch results in the production of a pot of metal of varying chemical composition and density according to depth,

as usually no arrangements are made for stirring the mixture. The variation in density of the metal results in the production of objectionable "wavy" and "cordy" glass upon blowing.

TANK FURNACES

When tank-furnaces are used, the strong blast of air and gas which plays through the "ports" in the side walls over the bath of metal, carries off the fine material of the sand, and a real loss in bulk occurs, as well as a change in chemical composition of the remainder. The other powdery material of the batch such as soda-ash (Na_2CO_3) melts too rapidly to be lost, but the fine silica dust is more refractory and "blowing-out" results before it can be melted. The statement that in America glass-making, sand of diameter less than $\frac{1}{8}$ in burns out in the batch is not borne out by British and Continental practice, where sands of diameter down to $\frac{1}{4}$ or even $\frac{1}{8}$ mm. ($\frac{1}{16}$ to $\frac{1}{8}$ inch) are continually in use. Fine sand of diameter $\frac{1}{4}$ to $\frac{1}{8}$ mm. diameter does not appear to be objectionable—rather the reverse, but it is not easy to find pure and well graded deposits of this character. The important point is that for most glasses, the melting of the batch should be rapid and even.

Shape of Grain.—Some disagreement exists as to how far the shape of the grains constituting a sand is of importance in glass-making. Most manufacturers, if they have a preference, lean towards the use of an angular or sub-angular sand. However, sands composed of rounded grains are successfully used for glass-making in the United States.

The most obvious reason for the preference for angular grains seems to be that the grains fuse more rapidly in the batch, the melting proceeding at the corners and edges of the grain. The tendency of the batch to pass freely, quickly and evenly into metal is thus increased.

These remarks do not apply altogether to the making of optical glass, where no danger of blowing out exists a long period of melting is required, and stirring is always adopted.

Other Considerations.—It is necessary that a glass-sand should be dry, for moisture present tends to form bubbles or otherwise spoil the glass or cause variation in its properties (e.g. in optical glass). For all special work, the sand, or batch including it, is dried in large ovens.

Freedom from organic matter should also be ensured, for it usually has a reducing action which is not always desired in glass-making (though coke is sometimes added for that purpose in making common glass, as, for example, where salt-cake is used). Organic matter is burnt out with the water during the roasting in the ovens.

Water and organic matter appear in the chemical analyses under "loss by ignition."

The ideal sand for making the best glass is thus one with practically 100 per cent silica free from all but the slightest trace of iron, and composed of angular grains of quartz (but not other forms of silica as well) all of the same size. The sand should also be dry and cleared from dust or any clayey coating on the grains. Although not so essential, it is desirable not to have organic matter present.

TREATMENT OF SANDS

Washing.—Many British sands may be improved by violent agitation with water. The improvement may be threefold; a better grading may result. It does not appear possible by washing to convert a second or third quality sand into a first quality one. An irreducible minimum of ironoxide always remains and cannot be washed away.

The washing is usually carried out in this country by means of rotary plant. The sand is fed in at one end of an iron cylinder which is rotated. Water pipes run through the upper part of the cylinder and spray the sand, which is forced down the chamber by a screw-action. The dirty water runs off at the opposite end. The sand is drained and usually is left to dry in the open air. In some cases it is washed twice over.

Although the best sands, such as those from Aylesbury and Fontainebleau, are not improved in the matter of iron-percentage by washing, they are frequently and advisedly treated in this way at the works when they are required for optical and special glass-work. The washing then removes dirt, dust, coal, other organic matter, etc., picked up during transport.

By experimental work with elutriators, etc., washing may be controlled so as to eliminate only the grades which it is desired shall be absent. For example, a current of velocity $3\frac{1}{2}$ mm. per sec. (42 ft. per hour) will carry off all particles of diameter less than 0.075 mm.

Drying and Burning.—Thorough drying is rarely attempted by exploiters of sands in this country, so has

often to be carried out at the glass works. The drying apparatus is usually a form of large oven, but in the United States, tier-dryers, rotary methods and steam-coils are used.

Apart from the mere improvement in color as the moisture is driven off, the burning of sand often affords a valuable indication of the approximate amount of iron present. The burning registers only the iron present as staining, and not that in the form of iron-bearing minerals, which usually remain unchanged. Black specks of coaly matter, which might otherwise at first sight be confused with magnetite or titanoferrite, then burn out and indicate their organic origin.

Magnetic Methods.—Sands bearing a considerable amount of heavy mineral residue are, as previously noted, generally unsuitable. Many of the heavy grains, particularly the oxides and ferro-magnesian silicates, react with the electro-magnet, and may be separated thereby from the quartz. In the United States glass-sands have been freed in this way from magnetite.

No chemical methods yet suggested have been both completely effective in cleaning a sand of iron and reasonably cheap at the same time.

Treatment of Crushed Rocks.—At the outset it may be pointed out that crushed sandstones and quartzites, or even crushed forms of silica, such as quartz, have never found much favor with British manufacturers. Similar materials, after suitable treatment, appear to be extensively utilized in the United States.

The importance of using well-graded sands especially for optical glass has been emphasized. The crushing of rocks always produces material of all sizes from a certain limit downwards. Mining engineers are still endeavoring to devise a machine that will grind or crush rocks to a fine, even grade without producing dust, which is waste material. The great evil of rock-crushing lies in the quantity of dust produced.

To produce an effective sand from this crushed material, the fine grades and dust must be washed away with suitably adjusted water currents, the velocities of which have been determined as a result of elutriation experiments. The mixture must also be sifted to remove coarse grades. The cost of quarrying, crushing, and sifting, has generally been already too great to permit of washing also, the price of the unwashed material being prohibitively high even in the neighborhood where it is produced. Considering also the high freights, it will be seen that it is improbable on these grounds alone, that crushed rocks even with high silica and low iron content, will replace glass-sands to any extent in this country.

The objections to the use of crushed rock-material in the actual manufacture of glass are serious. It has been pointed out that coarse grains produce "stones," and fine dust "blows out," entangles air bubbles, and gives glass which is not of the same density throughout. It is essential for optical glass more than any other that homogeneity should be obtained and defects and bubbles eliminated. As in the case of crushed quartz-crystals themselves, it is also objected by many glass-manufacturers that the metal produced from the crushed material tends to be "cordy" and "wavy," and to remain "sticky" too long during cooling, which also is protracted more than is desirable. Whether this is the result of the mixture of fine grades, of the presence of two allotropic modifications of quartz (for example, α and β forms differing crystallographically and physically) one possibly as matrix, of the different hydration of the silica acting as cement, or of the presence of inclusions in the quartz, is not known. Investigation is now being carried out upon the question.

A War-Time Sales Argument

ONE of the large meat-packing concerns suggests an interesting sales argument for retailers who find that their customers are buying smaller quantities of meat. The argument is that if the people in comfortable circumstances reduce the amount of food consumed by weight they will be inclined to make up this economy by purchasing choicer cuts and the very best quality in everything. In that class of trade where the retailers' customers are saving for patriotic reasons rather than personal economy, it is perfectly legitimate for merchants to urge that the choicest varieties of food be served during war times. Unfortunately for the validity of the argument, at least as far as beef is concerned, it is impossible to buy choice cuts of this meat in this country, except in a few of the larger cities, and in few shops even there.

It is well known to insiders that the greater proportion of the really first-class beef is shipped abroad, for the average Englishman would not touch the quality commonly sold in this country. Moreover, he doesn't pay any more for this first-class meat than we in America pay for second and third class beef.



Photos by the Press Illustrating Service, Inc.

In New York's Ghetto the inspector is testing the scale on which bread is weighed. In this bake shop the bread is made in large loaves and then cut to any desired weight. You can buy a slice or a loaf



This 'sidewalk' store does a rushing business. Everything is sold by bulk and the two scales which are continually busy are being closely examined before a small but interested neighborhood group

Safeguarding the People's Food

Food is the vital problem of the world today, with the rich because they cannot obtain some of the luxuries they are accustomed to, with the poor because they are unable to get the necessary amount and with everyone because of high prices. But besides the problem of quantity there are two other important phases of the food question that are liable to be lost sight of in the struggle for our daily necessities, and they are quality, and securing the quantity we pay for, or in other words, honest weights. It is this latter phase that is illustrated in the accompanying series of photographs taken in the great East Side of New York, which is typical of similar districts in many other large cities.

In these poorer districts where money is scarce, and close bargaining is the rule, for every penny must be made to yield its utmost value, there is a strong incentive for the small dealer in foods to tamper with his weights and measures, and to give short quantity. It may be said that the same practices prevail among more pretentious establishments, but the American people are so notoriously careless and easy going, so accustomed to petty dishonesty that little attention has been given to the matter in quarters where the strongest influence could be exerted. As a result of these conditions our law makers, who are politicians first, and representatives of the people last, have been slow to rectify the evils; but in New York State, for some years there have been more or less satisfactory laws relating to honest dealing, and these laws have been quite satisfactorily enforced, although they are the constant target for politicians who are more favorably impressed by the combined influence of the dealers than by the rights and welfare of the public.

Whenever questions relating to food have arisen there have been plenty of interested parties to come forward with the specious argument that the permission of a poorer quality, or more or less adulteration of food products, did no harm to the consumer, but was an advantage, as such products could be sold at lower prices. Such claims, however, are false from every point of view, for even if such inferior foods caused no immediate physical injury they are directly harmful by depriving the consumer of food value for which he has paid. Moreover, it has never been satisfactorily demonstrated that such food was offered to the public at a materially lower price. Nevertheless these arguments have always had weight with our law-makers, as well as that other plea, that care should be exercised in making restrictive laws—which were obviously the right of the consumer—lest "injustice" be done to vested interests. The fact remains, however, that these interests became vested because their promoters risked their money in questionable enterprises because they believed that individual responsibility for dishonest methods would be obscured and its identity lost in corporate organizations, and that means could be found to influence the form, or to circumvent the operation of such laws as might be enacted. That such investments, made with a deliberate intent to defraud the consumer, should be entitled to the tender solicitude with which they have been treated is difficult for the outsider to understand.

With what consideration dishonest purveyors of food have been treated is evident in the laws that have been enacted. After evading the subject for many years, Congress at last enacted what was officially known as the pure food law, but which, because of its peculiarities, was more popularly known as the "poor" food law. In its practical operation any dishonest dealer was permitted, on filing the alleged formula of the contents of his product, to label it as "guaranteed" by the Government, and actions brought with a view of enforcing the law were frequently quashed by department subordinates for their own personal reasons. Even with this scandalous condition of affairs it was several years before Congress moved to correct matters, and although the present laws are a considerable improvement over their predecessors, the penalties imposed by the courts are in too many cases merely nominal, and bear no adequate relation to the profits the defendants have made by their violation of the law.

The "joker" in all these laws has been in the provisions for the enforcement of the regulations, and the penalties prescribed, and it is an open question if we are not to have an experience of the same kind in the existing measures for the regulation of food. Immediately it was proposed to appoint a food dictator for the war, the same old cry of "justice" to vested interests was raised, and the danger of investing one man with too great power entirely ignoring the fact that ample safety was insured for the reason that if anything questionable was done by the dictator, there would be no question as to who was responsible, while in the case of a committee it is always possible to "pass the buck" in a way to obscure the issue and absolve every one. As a result it is an open question if Mr. Hoover has been clothed with enough power and authority to enable him to produce effective results. If his efforts for the protection of the public are not successful the blame should be placed squarely where it belongs—on a Congress that has too frequently permitted itself to be influenced by a few men whose loyalty is, to say the least, decidedly doubtful.

In connection with this matter it is interesting, and enlightening, to recall that during the past few years many thousands of dollars have been expended on Congressional committees for investigating the high cost of living, with the usual poverty of results as far as can be ascertained; but if these costly committees actually gathered any information of value, which has not as yet been made public, now is the time to turn the facts over to Mr. Hoover to assist him in his work.

River Sanctity and the Engineer

THE economic beneficence of the vast irrigation systems of Northern India is so great and manifest that their provision may well be regarded by the cultivator as an act of piety on the part of the Sircar. Yet of late religious scruples have interfered with, and caused some modification of, improvements of the Ganges canal system by the provision of permanent headworks near Hardwar. Although care was taken in drawing up the plans not to infringe in any way on the provision for the bathing and other accommodation of the numerous pilgrims who visit Hardwar, especially at the great

Kumbh-mela which takes place every twelfth year, a memorial signed by a number of Hindu ruling princes and other influential Hindus was recently presented to the Government alleging that certain features of the headworks at Bhimgoda, $1\frac{1}{4}$ mile upstream from Hardwar, were objectionable to the religious sentiments of the community. As a result a conference with representatives of the memorialists was held *in situ* by Sir James Meston, the Lieutenant-Governor of the United Provinces, accompanied by his chief secretary and irrigation officers, and the importance attaching to the occasion may be judged by the fact that the conference, which lasted two days, was attended by some of the greatest Hindu ruling chiefs. The points at issue were discussed with the aid of a large model of the headworks. At the close Sir James Meston was able to announce that the chief engineer had agreed to certain changes being made in the construction of the new works. These were declared by the ruling chiefs present to be satisfactory, and were agreed to by all the representatives of the memorialists. The Lieutenant-Governor is to be congratulated on a settlement which must have been the more welcome to him from recollection of the extent to which Moslem feeling was convulsed early in his rule by the proposal to remove and rebuild out-offices of a mosque at Cawnpore for purposes of road improvement. The incident is interesting as showing how often the engineer in India has to take into account factors and equations such as rarely, if ever, interfere with the designs and plans of his fellows in Western lands.

Magneto-Ionization

In a paper read before the R. Accad. delle Scienze dell' Istituto di Bologna, in March of this year, Prof. A. Righi returns to the question of magneto-ionization, already dealt with in previous papers. A beam of X-rays ionizes the gas between two metal plates which are suitably connected to an electrometer and an accumulator battery. A magnetic field can be created in a direction parallel to the plane of the plates. Without the latter field the voltage-current curve shows the usual features of a saturated phase followed by one in which ionization by collision is prominent. When a magnetic field of 430 gauss is super-imposed, there is found a current decrease for the lower voltages, i.e., in the earlier portion of the saturated phase, but for voltages of 400 or above the current is slightly increased. This is ascribed by the author to the action of the magnetic field in promoting ionization. In the opinion of the writer of this note Prof. Righi's interpretation of his results is by no means the only one which is possible, and though his ingenious experiments are of great interest, his theory will need further support before it obtains general acceptance. In particular, it will be necessary to show that the increase of current is not caused by the oblique, and therefore longer paths of the ions under the joint actions of the two fields. When the saturated phase is passed, any increase in the distance traveled over by the negative ions means more opportunities for the production of further ions by collisions, and this may be all that is necessary to explain the results.—*Nature*.



Buying live poultry on the East Side. The Hebrews are forbidden by religious law to eat any but fresh killed fowl. These are killed according to ritual by the Schochet. Only a specially prepared cutting edge may be used



Testing the pan scales at the great open air fish market. If these prove incorrect, a hammer is used to smash them and the use of the faulty scales proves a losing game for the vendor

A Motor Ambulance Driver's Notes from the Front

Now that the weather is inclined to assist instead of to hinder the cause of the Allies out here, the impressions that a motor person gets are somewhat different from those induced by the recent southwesterly gales. It was no picnic to come back a few miles with a rotten canvas hood against an eighty miles an hour gusty wind. And it did blow. Good old-established canvas marquees fell like decayed giants to the first burst one fearful Sunday night.

ROUGH WEATHER

Nothing that was double, or even treble, pegged could withstand those awful driving gusts. When one drove directly ahead into the storm the whole frail fabric of one's ambulance body reared and flapped until the eyelets became slits and the canvas ribbons, and even the wounded men's blankets within were blown for miles along the road as the gale caught them and tore them off. The rain and hail filled every crevice in the road with flood water. New roads became small rivers, where they bit into the hillocks of the rolling countryside. Into a meter of water one would drive one's car, followed by the rest of the convoy, and then most likely stop with a magneto missing fire and a carburettor filled with water. One expects this in winter, and makes oneself acquainted as far as possible with the location of any pools of water that may lie in one's course, but in summer one is not prepared for such experiences.

WIND AND MUD

That is only a slight trouble comparatively. Away there in the lines the chalky trenches become filled with a milky mixture, and the scum of the miry communication works is shot out on to the road, to form an ideal skidding surface through which no studs will bite. Fancy trying to turn an ambulance on such a surface with a high wind pushing the car bodily crabwise into a most unsavory ditch which is supposed to drain the roadway, but which really does the reverse. One must drive well and with a lot of luck to escape some sort of *panne* when record March gales come in August.

The discussions are still mainly concerning cars and engines, but the meet of motorists now is almost always comprised of men whose talk is of aero engines—those wonderful Clerget, Beardmore and Rhône engines putting planes through the air at 100 m.p.h. Those are the engines that we are anxious to know.

American aeronauts can tell weird tales of night flights. After a heavy day's work we struck a little mess of American-French pilots, and my forensic American friend secured for us a warm welcome by calling a well-known pilot whom he apparently had known a long time a some kind of nasty something. A brisk interchange of pure Yank yap was the passport for us all.

FORMATION FLYING

Formation flying by night has terrors of its own. What must the feelings have been of the observer sitting well ahead in the nacelle of a powerful biplane as he flew in squadron with seven comrades all grouped around, as per instruction, when, as the deep darkness of a lowering cloud enveloped the squadron, the observer lost sight of the tail lights ahead, and in a few minutes, to his horror, found himself almost touching the tail of the

machine in front, which had slowed down with mixture trouble, and had been caught by the other plane as it deviated into the wash and was twisted about. Both machines were out of control, but the observer's wits solved the situation. The man in trouble would naturally dive, and so the wary observer signalled his hard-worked pilot behind to climb. This he did despite the wash and the bad control, and so the crash below was averted.

Considering the terrific explosives carried on each machine, and the almost instantaneous meeting, it is rather a miracle that they managed to clear each other and to remain in the air. If they had both dived—one can scarcely think of the horrors of such a thing, 12,000 feet up, and carrying perhaps half a ton of bombs between them!

DARING AMERICAN AIRMEN

Another pair of Yankee dare devils went up one bright morning and sallied forth over the German lines. They put paid to a German machine well inside the enemy lines, and they came down, too, to see that it was outed. All seeming well, they landed and managed to retrieve a gun and ammunition from the wrecked plane, and then to rise just as a squadron of Uhlans came across country to search for the wrecked plane. While one man threw a light into the mass of wreckage the other kept the Uhlans at bay with the gun taken from the enemy plane, and the pair having risen well into the air returned to pepper the Uhlans, and then climbed higher to get back home. On the way they were attacked by a daring Boche, who tried to put them out as he flashed by. So close did he pass that the Yank observer hurled an empty drum at the machine, and was fortunate enough to smash the propeller. So down went that machine, and the gay pair of Yanks returned to their own lines with their captured gun and a sieve of a biplane that only the good engine had managed to keep up.

The history of the American Air Service in France is full of the gay madness of their pilots. They are second to none. They can manage any stunt that can be tried by a bird. If they want a sudden lift they plunge their machines into the wind just like a swift and lift yards at a time.

SCRAPING HOME WITH DAMAGED MACHINES

I wish your readers could have listened to the tales of machines dragging home with broken pistons, burst cylinders, and misfiring. Sometimes a magneto would pick up just as the machine was almost down and enable it miraculously to reach its own lines before the final collapse came. It is quite a horror of its own to have that petering out feeling just as a pilot is nearing his own lines and things are looking rosy for his peace of mind. There is at least one case on record where a pilot landed and rescued a fellow pilot right in front of an enemy battery of heavy guns, which fortunately could not be brought to bear upon the airmen under the circumstances, although, of course, there was enemy rifle fire to dodge. What a game for the gods!—R. CARTWRIGHT, in *The Autocar*.

Migration of Projectiles in the Blood Stream

We recorded recently a case, reported by an American surgeon in France, of the migration of a fragment of shell from the femoral vein to the right ventricle. The condition remained unsuspected until the autopsy. The story has been capped by Dr. Specht, surgeon to a

German military hospital, who found a shell fragment in the left ventricle at the autopsy on a man who died of sepsis after a deep wound of the thigh. In this case the foramen ovale was widely open and the fragment must have passed through the aperture to the position beneath the flap of the mitral valve where it was found. The man lived ten days after his injury, but no symptom whatever had pointed to any involvement of the heart. Dr. A. Rudolf Jaffé, assistant surgeon at the same hospital, relates a series of interesting cases from German literature of which the most remarkable was recorded by Freund and Caspersohn, who removed from the lumen of the right ventricle a shrapnel ball 13 mm. in diameter. In this case, although the wound was situated at the edge of the right costal arch in the nipple line, and the projectile might therefore have entered the right ventricle directly, the surgeons found no sign of wound of the heart wall nor effusion into the pericardium, and concluded that the ball had entered the vena cava, thus reaching the ventricle indirectly. As the patient recovered no opportunity offered for verification of this assumption. Jaffé adds a case observed by himself, in which a Russian rifle bullet, wounding the pelvis near the posterior spine of the ilium, entered the inferior vena cava and was carried thence to the right ventricle, where it was found at the autopsy lying beneath a flap of the tricuspid valve. No thrombus was present, but the endocardium and valve were swollen and blood-stained. In this case the patient had complained during life of pain over the heart. The occurrence of free projectiles in the blood stream, although doubtless very rare, has already become something more than a surgical curiosity, and its possibility may well be borne in mind by those who observe anomalous symptoms after gunshot wounds, especially when the projectile is not found.—*The Lancet*.

Used Cartridge Cases

The interest that the ammunition manufacturer takes in cartridge brass does not cease with the production of the finished cartridge case, for of the components of a cartridge the case alone is left undestroyed, the propellant and the shell or bullet being completely destroyed so far as further useful recovery is concerned.

Cases other than small arms may, if not seriously mechanically damaged, be re-formed to size and used again. Small arms cases, however, after once being fired, suffer a deterioration which not only prevents them from being used a second time, but which also prevents them from being utilized as scrap for casting cartridge brass.

The causes of this deterioration are metallic mercury and antimony salts, products from the explosion of the ingredients of the percussion cap. A portion of these products is retained on the interior surface of the case. From the point of view of re-using the case as a case, it is the weakening effect off the mercury on the strength of the brass that gives the trouble. From the point of view of using the fired cases as scrap for re-melting, it is the antimony which is the bugbear. Much may be done by washing the fired cases in suitable solutions, but even after repeated treatment in this way, when put into a heat for best cartridge metal, antimony will be found in harmful quantities in the ingot.—From a paper on "Cartridge Brass" by H. W. BROWNSON before the Society of Chem. Ind.

The Occurrence in Virginia of Green-Gilled Oysters Similar to Those of Marennes

By Philip H. Mitchell and Raymond L. Barney

THE appearance of green-gilled oysters in Lynnhaven Bay, Va., in such large quantities during the fall and early winter of 1915 that several of the oystermen of the vicinity were unable to sell their product because of the dark-colored gills led to this investigation. The problem is of considerable economic interest since the entire oyster industry of Chesapeake Bay was at stake, the green-gilled oysters being found in locations many miles distant from one another. Moreover, if this outbreak could be proved to be an exact reproduction of the greening of the popular Marennes oysters, it might be the basis of oyster culture in Virginia from an entirely new point of view. Further than this, the study offered an interesting scientific problem which narrowed itself down, in the consideration of the writers, to a physiological and chemical study of the pigment and the manner in which the oyster re-acted to it. The main purpose, however, in this study has been to find whether or not the greening of the gills in the Lynnhaven oysters is the same as that in the choice Marennes oysters, for a glance at our American oysters shows that they are very similar in general appearance and in the distribution of the pigment to the descriptions and drawings of the Marennes oysters.

HISTORY

In the past there has been considerable work done on the green coloration of oysters, especially in Europe. Papers have been written on both the green-gilled and the copper-green oysters.

The genuine green-gilled oyster was first worked on by M. Gaillon, who published his first paper in 1820. In this paper he explained the French custom of placing the oysters in claires or large reservoirs just within the high-tide mark and allowing them to remain there for a considerable length of time or until the gills and palps showed the green tint. He recognized that if the tanks contained a certain diatom, *Navicula ostrearia*, in large quantities, the oysters would take on the green coloration, but that when the oysters were taken from the tanks and placed in fresh sea water, or allowed to remain in the tanks after the growth of the diatoms had ceased, the oysters would arrive gradually at their normal color in three or four weeks. Furthermore, Gaillon pointed out that common chlorophyll was not the coloring matter. His conclusion that the *Navicula ostrearia* was the cause of the greening of Marennes oysters was accepted and corroborated by other European biologists later in the century. Gaillon, however, offered no proof as to how the green substance reached the gills. He noticed that no other organs of the body except the gills and palps were ever colored, but he did not try to show how the coloration took place. He intimated that perhaps the green substance entered the gills through the gill filaments, but he could not offer scientific evidence of such entrance.

Valenciennes in 1841 drew attention to the fact that beside the gills and palps, the liver and intestines often showed a green tint, while the heart, reproductive system, muscles, and blood showed no abnormal color whatsoever.

Gaillon, in a second paper in 1824, suggested what appeared to be the proper explanation of the green colorations in the gills, palps, liver, and intestines by saying that the coloring material is taken into the alimentary canal and that the oyster's gill tissue selects and deposits the coloring matter much the same as the osseous tissue of pigs fed on madder selects and deposits the red coloring of that plant. Thus it will be seen that Valenciennes in 1841 was hardly more than corroborating the work done by Gaillon in 1821 and 1824. Valenciennes, however, did considerable work on the chemistry of the pigment. He found that the coloring material of green-gilled oysters was insoluble in water, alcohol, ether, weak alkalis, or weak acids and that the only reagents that would dissolve the pigment were those that destroyed it forthwith. He, furthermore, came to the conclusion that the green-gilled pigment had no connection whatsoever with any metallic element, thus putting the green-gilled problem in a different category from the copper-green oyster with which it had oftentimes been confounded.

In 1861 Coste brought forth the suggestion that the greening of Marennes oysters was due to iron salts in the soil on the bottoms of the claires. This theory had been advanced several times, but Bornet and Ad. Chatin

showed without much doubt that in certain places the oysters in the claires would remain indefinitely white and then, suddenly, would take on the green coloration, due in their estimation to a change in the flora of the park and not because of the fact that the floor of the claire had changed in its elemental composition. Sullivan in 1870 came to the conclusion that green-gilled oysters contained no copper. Dyer in 1877 showed that oysters put in dishes that contained *Navicula ostrearia* became green in 36 hours. Puysegur in 1880 published the results of some of his observations on greengills, mentioning especially that he had turned the gills of normal oysters green by immersing the oysters for only a few hours in water that contained the *Navicula*. Barney, Ducaisne, and others observed the same results from similar experiments.

In 1886 Ray Lankester, the eminent English biologist, affirmed the work of Valenciennes as regards the absence of any metallic compound in the green pigment that caused the gill coloration. In this paper Lankester made it his purpose to demonstrate three things:

1. That the oysters do swallow the *Navicula ostrearia*.
2. That a pigment having the same peculiarities determined by Valenciennes, or from which Valenciennes's pigment could be derived, actually occurs in the *Navicula ostrearia*.
3. That there is some mechanism in the oyster by which the pigment of the *Navicula ostrearia*, being taken into the oyster's alimentary canal, can be absorbed and deposited in the gills and palps.

These points Lankester well brought out. He concluded, through the fact that he found many frustules of the diatoms in the intestines and stomachs of green-gilled oysters that they must have swallowed them. Further than that, he observed the pigment of the *Navicula ostrearia* chemically and spectroscopically and found it to have exactly the same properties as the green pigment of the Marennes oyster. Lankester also did considerable work on the histology of the oyster gill in an effort to find and demonstrate the exact distribution of the pigment. This distribution of green material he found to be in amoeboid leucocytes that work their way through the epithelial cells of the gills and move around on the external surface of the gills. These cells he called "secretion cells," and they are found on all normal oyster gills. With this work Lankester also published a minute description and a set of colored drawings of the *Navicula ostrearia* and the distribution of its pigment throughout the oyster.

In 1899 Herdman and Boyce, two English investigators, published a paper on "Oysters and Disease," in which they drew attention to the fact that copper-green oysters and green-gilled oysters were two different abnormalities. This paper was merely a review of the work that had been done on the green oysters up to that time, supplemented by a study of the histology of the two different types of green abnormality. Ryder, whose work has been published in several United States Fish Commission reports, did much investigation on green oysters, but the copper-green oyster received his attention especially.

The only papers dealing with the conditions that show the effect environment may have on the growth of the *Navicula ostrearia* and the consequent greening of the oysters are those by Boubés and Calvet. Boubés, in his "L'ostreiculture à Arcachon," gives a general survey of natural, legal, and economic conditions affecting the oyster industry at Arcachon, contrasting these with circumstances at Marennes. In this publication he mentions the most important fact that, when the claires are allowed to get too salt, the product, the greengill, is not so good. He intimates in this statement that a high specific gravity is not conducive to the life of *Navicula ostrearia*. Calvet, 1910, in "Du Vertissement des Huitres," discusses the conditions that tend toward an optimum "greening" of oysters left in the claires, taking into consideration the temperature, the specific gravity of the water, the depth of the water, the nature of the bottom, and the effect of light on the growth of the *Navicula ostrearia*, and therewith the greening of the gills.

THE GREEN-GILLED OYSTERS OF VIRGINIA

The oysters found to possess this abnormal condition in Virginia were the large typical Chesapeake oysters. The gills at the height of the epidemic showed a green color, which extended in many cases up into the palps, turning them, also, a greenish color. The liver appeared

a somewhat darker brown than in the normal oyster, but the rest of the oyster's body seemed perfectly normal. The larger number of the oysters observed were in a well-nourished condition and appeared very "fat." Indeed, the people in the vicinity of Lynnhaven used them freely, claiming that they possessed a more delicate flavor than the ordinary white oyster. The oyster dealers of the place also shipped considerable quantities to distant destinations where, according to reports, they received ready sale.

The epidemic itself was spread over large areas, which, in some cases, were many miles distant from one another. Lynnhaven Bay, with the two large creeks that combine to form it, was the seat of the most serious outbreak at the time of this study. The same location had been reported to have suffered in a like manner in 1912. From testimony taken from various oystermen of Hampton and Phoebus, greengill had appeared at different dates, but all who were interviewed agreed that the last general epidemic occurred in 1912. At that time the greengill was distributed the entire length of Hampton Bar and Flats from Newport News to Phoebus and Mill Creek, and both the northwest and southwest branches of Back River also suffered. The present outbreak again affected Mill Creek and both branches of Back River. Farther north and more on the open coast greengill was found in considerable quantity on Drum Island Flats, but Hampton Bar and Flats at the time of this investigation were free of the epidemic. It was learned, however, that oyster beds from Cobbs Island down to Goodwins Island had suffered in various years and at various locations from greengill.

An effort was made in taking these data to get general information from those interviewed in regard to weather conditions, temperature, depth of water, and general locations of outbreaks with their relationship to the greening, but with little success. The theory offered by one individual would be contradicted by the next person interviewed, so that no facts or ideas common to all observers were obtained from those most closely connected with the oyster industry.

Not being able to gain specific knowledge of the general relationships of greengill with weather, temperature, salinity, etc., from interviews, and at the same time trying to find some connection between the true Marennes green-gilled oyster and the greengill at hand, it was decided to take water samples from locations where the epidemic was prevalent and observe the temperature, salinity, and the vegetable life in the water. Samples thus studied were taken on January 4th, 5th and 6th, 1916. The weather of these days was rainy or cloudy, with the temperature varying from the freezing point to about 15° C. The water samples were taken from places where the water was not more than six inches deep and which, therefore, was open to a considerable change of temperature during the day and night. No doubt the temperature of the water during the night lowered to within 2 or 3° C. of freezing, while during the day it increased to perhaps 12 or 13° C. For about a week before these samples were collected, there had been a heavy storm blowing from the southeast, and the bottoms of Lynnhaven Bay and the coves, which up to the time of the storm were reported to be covered with a green carpet of vegetable life, showed nothing but the typical gray clayey mud with the water very much roiled. Samples were taken, however, and in five of the six samples obtained in various parts of Lynnhaven Bay diatoms were found that exactly answered the description of the *Navicula ostrearia* as set forth by Lankester. The temperature of the water ranged from 10 and 11° C. in shallow places to 5 and 6° C. in the deeper water. The specific gravity of the samples varied from 1.015 to 1.019.

At the same time with these observations, examinations were made of the contents of the stomachs of several oysters just taken from Croonenbergh's Bar, and in every case diatoms or the frustules of diatoms were found that were of exact description of the *Navicula ostrearia*.

In a similar manner, as at Lynnhaven, the water of Back River was studied. Wherever a water sample was taken, oysters were dredged and in every case showed the greengill. The weather there was the same as had been experienced at Lynnhaven, and the water was very much roiled. The specific gravity and temperature of the water varied from 1.015 to 1.017 and from 8.5 to 10° C., respectively. In the five samples taken,

*Contribution from the United States Fisheries Biological Station, Woods Hole, Mass., and the Biological Laboratory of Brown University published in Bulletin of the Bureau of Fisheries, Vol. XXX, 1916-16, Document No. 850, 1917.

approximately half a mile apart, two contained diatoms which were identified as *Navicula ostrearia*.

The *Navicula ostrearia* was also found in the green scum that clung to the shell of one of the oysters dredged in this observation.

On January 19th, 1916, a sample of water from the western arm of Lynnhaven Bay, Va., was examined after a two days' shipment during very cold weather. The sample, despite the cold weather, yielded many different kinds of vegetable organisms, among which was observed the *Navicula ostrearia*. On February 18th, 1916, a water sample from Lynnhaven Bay was examined that showed by far a larger number of organisms with the characteristic *Navicula ostrearia* appearance than any water sample yet taken. On March 17th another water sample was received from Lynnhaven and examined, but this showed no *Navicula* organisms whatsoever. Possibly this absence of the above-mentioned organisms was due to the fact that the sample was taken in deeper water and with a large bottle that had a very narrow neck. The shape of the bottle was in itself enough to prevent obtaining an average and acceptable sample. On April 17th, 1916, another water sample from Lynnhaven arrived and was examined. This, however, showed no *Navicula*, but the absence on this occasion of the diatoms could be reasonably laid to the report that the greengills were clearing up in the bay and that no very green oysters could be found. Those which did have any pigment were very pale. On June 14th, 1916, a similar water sample was examined, but this showed no *Navicula ostrearia*.

In an effort to ascertain whether the *Navicula ostrearia* inhabited the waters where the greengill had never been known to exist, and to further the theory that the blue diatom caused the greening, Narragansett Bay was studied in a general way with respect to its diatom growth. In samples taken in different parts of the bay and in sheltered locations along some of its inlets no diatoms that in any way answered the description of *Navicula ostrearia* were found. Further than that no classification of American diatoms that could be obtained gave any description of a *Navicula* of the characteristics that were typical of the organism found in the southern waters.

The examination of the alimentary canal of 13 oysters with greengills which arrived some three or four days after shipment from Virginia showed in every case the presence of *Navicula ostrearia* frustules in the digestive tract. In eight oysters the stomach contents were examined; in three the intestines were opened and their contents examined; while in the two others excrement was obtained from the rectum and in every case the presence of the sought-for frustules was determined.

The frustules of the *Navicula ostrearia* found in the Chesapeake answer perfectly the descriptions given of the frustules of the Marennes *Navicula*.¹ They show a thick and distinct raphe with a valve difficult to distinguish. At a glance they appear smooth without transverse striae, these being scarcely visible. The appearance of the Virginia *Navicula ostrearia* compares exactly with that of the European diatom as set forth in Van Huerck's classification, "A Treatise on the Diatomaceae."

HISTOLOGY OF THE GREENGILL

In order to study the distribution of the green pigment in the gills, histological sections were cut and examined microscopically. The method followed was simply to kill the tissue in HgCl₂, and then run it up through soft and hard paraffin, cut, and finally stain with differential stains. Haiden's hematoxylin and eosin or orange G seemed to answer the purpose very well. It was found that the pigment was localized in relatively large, irregularly shaped cells which gave a granular green appearance. These cells did not react to any stain to give a coloring to them but remained green under all conditions. The pigment looked somewhat darker green after staining than it appeared in smears of the gill unstained, but this was probably due to a slight darkening that Haiden's had on the pigmented cells or because of the surrounding tissue which was stained very darkly. The location of these cells was in the epithelial tissue of the gill filaments and along the epithelium which lined the interlamellar water space, especially in the vicinity of the interlamellar junctions. The appearance and location of these green cells exactly coincides with the description that Lankester gives of his "secretion" cells.

White gills of Narragansett Bay oysters were studied histologically by the same methods that were used in the greengill study. These showed exactly the same distribution of the large, irregular-shaped cells with granular protoplasm. These, however, were stained by orange G or eosin. The location and appearance of these cells were the same as of the pigmented cells in the greengills. This demonstrated that secretion cells were always present in and on the gills. Lankester said that these cells "furnish precisely the mechanism which we should

expect to find in order that the blue pigment absorbed by the blood of the oyster from the contents of the alimentary canal, namely, from ingested *Navicula ostrearia*, should be deposited at a particular spot on the animal's body. These secretion cells do not occur on other parts of the external surface of the oyster. They are limited to the surface of the branchiae and to the adoral surface of the labial tentacles."

In a continuance of the microscopic study of the greengill, smears were made of the teased tissue of the pigmented gills. These showed the presence of the pigment in large irregularly shaped cells, the granular cytoplasm being distinctly green. These cells moved about in a typical amoeboid manner, which led to the conclusion that possibly the secretion cells were nothing more than leucocytes. Smears of this gill tissue were compared with smears of white gills, and in each case the characteristic amoeboid leucocytes appeared. Wright's bloodstain was then used on several smears, and in each case the green leucocytes stood out green against those of the white gill, which stained red with the eosin of the stain.

To prove that the *Navicula ostrearia* was the actual cause of the greening, an attempt was made to develop greengill in a normal white oyster taken from Narragansett Bay, where the greengill has never been known. The oyster was placed in aerated sea water which contained the *Navicula ostrearia*. After a week's time the oyster was examined and showed a pale green color in its gill tissue. To further prove that deposits of green pigment had occurred, smears were made of the gill tissue, and in each case they showed the characteristic green amoeboid cells. Experiments to substantiate this study would have been continued, but the water samples subsequently obtained from Virginia were never very rich in diatom growth, and such efforts on the water samples received seemed futile. A control, however, was run on this greening experiment by placing an oyster from Narragansett Bay into aerated sea water from Virginia which contained no *Navicula ostrearia*. After a week's time this oyster was examined and showed no green coloration whatsoever. The secretion cells examined in a smear of the gills were normal in appearance.

The fact that green-gilled oysters depended on the presence of blue diatoms in considerable quantity, and the fact that the water samples from Virginia contained very few of the desired *Navicula* with which to carry on greening under controlled conditions, suggested the possibility of growing the *Navicula* in artificial culture media. Efforts, however, were all with negative results. Several culture media were tried at different temperatures, but none seemed to help in cultivating the organism.

THE CHEMISTRY OF GREEN-GILLED OYSTERS

The only chemical work that had been done on the green pigment of Marennes oysters at the time of this investigation was summed up in Lankester's work. That work shows that the pigment was insoluble in water, dilute acids, dilute alkalis, alcohol, ether, glycerine, and benzol, either hot or cold, and that the coloration was not due to the presence of copper or any other metallic element. It shows further that strong acids or alkalis dissolved but at the same time destroyed the pigment.

Lankester examined spectroscopically green-gilled tissue with the use of a powerful ray of light. He found, however, that this demonstrated no isolated absorption bands in the spectrum. He also examined in like manner a mass of *Navicula ostrearia*, but detected no absorption bands in the spectrum.

The first investigations in this problem carried on in respect to the chemistry of the greengills was to ascertain whether or not there was any copper present in the gills. Four grams of desiccated greengill were digested in sulphuric acid and potassium nitrate. After complete digestion, and after making the solution ammoniacal, only the faintest trace of yellowish-green color could be detected. This test showed the absence of all but the faintest trace of copper, which has been found to be present in all oysters. This experiment was repeated with the same result. Lankester said in this connection: "Whilst there are so many considerations which explain the origin of the notion that copper may be responsible for the green color of the 'huîtres de Marennes,' although that metal has nothing to do with it, it is extremely remarkable as a coincidence that of late years it should have been established that copper in minute quantities is a normal constituent of the blood of molluscs." Further evidence that the greengill contained no abnormal amount of copper was seen in the fact that the people of the vicinity who ate the oysters raw in considerable quantities noticed no abnormal taste. Surely had the green color been due to a copper compound, there would

¹Dr. Albert Mann has examined some of the material and has confirmed the authors' identification of the Chesapeake diatom as *Navicula ostrearia*.

have been enough present in specimens so intensely pigmented to have given the so-called coppery taste that many observers claim is characteristic of oyster containing excessive copper.

The solubilities of the pigment were then studied, using the green-gilled tissue as freshly taken from the living oyster and the tissue after it had been thoroughly dehydrated. The gills of several oysters extracted in alcohol, 95 or 100 per cent, gave a slight yellowish-green coloration to the extract. A carbon disulphide extract of green-gills yielded also a yellow-colored solution. But when either one followed the other the second was always somewhat paler. The gills, however, always remained green after such extraction, showing that the green pigment was insoluble in carbon disulphide or alcohol. White oysters yielded the same results. So it appears that these extractions were merely dissolving a pigment common to any oyster gill, probably a lipochrome. A yellow carbon disulphide extract was evaporated down and left a yellow residue that was insoluble in water. This residue was mixed with oil and subjected to the Crampton-Simon test for the detection of carotin. The result was negative. Chloroform and ether were also turned a yellow color when used to extract the greengill, but as in the case of other solvents, the extract did not differ from that obtained from normal oysters.

In dehydrating the green-gilled tissue, the following reagents were used in the order mentioned: Alcohol, ether, and carbon tetrachloride. This method always left the carbon tetrachloride slightly yellow colored and gave a dark green residue of dried gill tissue. This dehydrated tissue was then ground and used in solubility tests that followed. Solvents in different strengths of alkali and acid were used, with the results that the pigment was practically insoluble. Hot or cold water did not dissolve the green pigment.

After the pigment had been shown to be insoluble in the common solvents, experiments were undertaken to ascertain if there was any chemical combination of the pigment with a protein or fat molecule.

The spectroscopic examination of the green-gilled saponification showed an absorption band covering the violet end of the spectrum. Examination of the normal gill material obtained from saponification showed no shadows whatsoever in the spectrum.

To establish the fact that the green coloration of the gills in Virginia oysters was not due to the presence of a bacterial pigment, the pigmented gills were subjected to bacteriological examination.

Small pieces of the pigmented gill were placed in sterile water and shaken up thoroughly and then plated out on nutrient agar in Petri dishes, with the usual bacteriological technique. No color-producing organisms were obtained in three trials. Abundant colonies of white bacteria were observed.

CONCLUSION

The investigations seem to warrant the following conclusions:

1. The Chesapeake green-gilled oyster is the same as the so-called Marennes oyster.

This conclusion is reached since the Virginia oyster corresponds exactly to the descriptions of the Marennes oyster in general appearance and in microscopic examination. The greengills and palps of our southern oyster coincide precisely with the descriptions and drawings of the French oysters, and the method of distribution by secretion cells and the location of the pigment in definite tissues of the gills, as explained by Lankester, is the same as has been found in these observations of the Lynnhaven oyster. A diatom answering the same description as the *Navicula ostrearia*, recognized as the cause of the greening of Marennes oysters, has been identified wherever green oysters were found in the Chesapeake. The frustules of the diatom have also been obtained from the intestines of the green oysters in this observation exactly as Lankester noted in his study of the Marennes oyster. Again, this investigation agrees thoroughly with the conclusions of several European workers that the pigmentation of the gill can occur by allowing the oyster to remain in sea water in which there are *Navicula ostrearia*, but that there is no coloration if the *Navicula* are absent.

The observations in this investigation on the chemistry of the pigment of Chesapeake green oysters are exactly the same as those made on the Marennes greengills by Lankester. The extreme insolubility of the pigment noted by this investigator as characteristic of the European oyster is in direct harmony with the studies recorded in this investigation.

2. No evidence that the coloration of the gills of Chesapeake green oysters was due to bacteria was found in the investigation.

3. The pigment found in the greengills of Chesapeake Bay oysters yields a saponification product that shows an absorption band covering the violet of the spectrum.

$$50 \left(\text{value of } f \text{ for } 50\text{-ft. plank} \right) + (L-50) \left(\text{estimated value of } f \text{ for last foot of } 50\text{-ft. plank} \right)$$

L

The figures given in some text-books differ from those obtained in this way from Froude's planks, partly because of Mr. R. E. Froude's "O" constants published in 1888,⁴ or because of weight being given to Tideman's or other experimental results, but the departure is never very serious, and is only in detail and not in method.

6. There are three assumptions made in this procedure:—

(1) that the resistance of a solid body and a plank of the same wetted area and length are sensibly the same; (2) that the resistance of long planks at high speeds can be calculated from the short plank results by the method given; (3) that the quality of the ship's surface is the same as that of the smooth planks.

W. Froude was himself aware that this was merely a means to an end, and Sir William White, in his Manual, states that "it has been suggested that this generalization requires further and more extended experimental verification before it can be accepted absolutely, especially for ships of great length."

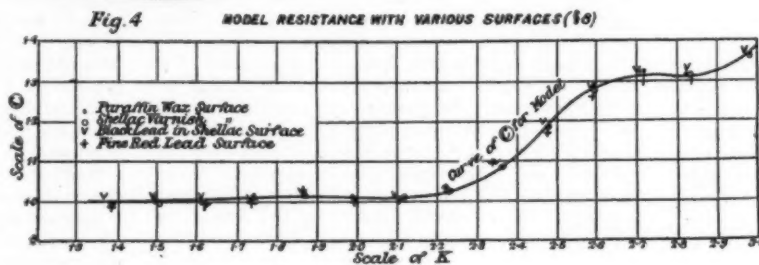
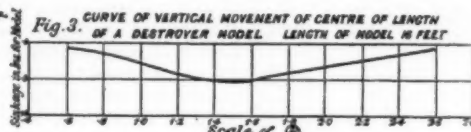
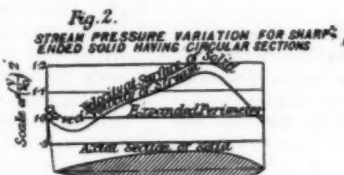
It will be seen from 4 that, although assumption (1) is sufficiently exact for fine and relatively long models, the body of the form has some effect as the prismatic coefficient increases. This conclusion is supported by the fact that, if the theoretical stream velocities around any solid form are obtained by calculation, it will be found that the mean value of the rubbing velocity of the streams and the form generally exceeds the velocity of the form itself, the excess varying with the fullness. This statement is made as the result of calculations with two-dimensional flow generally, but it has also been found to apply to the surface streams of a light cruiser at wave-making speeds. A

three-dimensional case has been worked out by Mr. Kent, and the form and velocity curve are given in Fig. 2 (above). This shows that the square of the rubbing velocity is 1.06 times the square of the stream velocity, the prismatic coefficient being 0.53. That this excess velocity is obtained in practice with all models is demonstrated by the fact that these models when in motion through the water sink bodily in space, and this sinkage is known to be realized in the ship. The passage of the water past the ship involves some velocity and pressure variation of all the stream lines in its locality. When the velocity of the particles of water is high, energy considerations require either a fall in space or a drop in pressure. At the free surface the pressure cannot change, and the water therefore changes level; but under the form some drop in pressure may be realized. Whichever form the change takes, any increase in stream velocity must tend to cause the ship to fall in space, in order to receive the same water support as before. To illustrate this point, a typical curve of vertical movement of the center of length of a destroyer model is given in Fig. 3 (above). It will be seen that there is a tendency to rise when the speed has risen above that corresponding to $P = 1.5$ (i. e., when the hollow of the entrance wave is working along the stern of the vessel), but even at a speed corresponding to 50 knots for a 300 ft. ship the model is below its still-water position.

7. With regard to assumption (2), the author in a recent paper suggested another method of estimating the resistances of long surfaces from the shorter plank results. This method is based upon the law of dynamic similarity, of which some account was given to this Institution by Dr. Stanton in 1912, vol. liv.⁵ The estimates of skin friction for ships made in this way are generally less than those obtained in the older way. This difference increases as length is increased and becomes important for lengths above about 250 ft. Thus for a 600-ft. ship of ordinary form at 20 knots the estimated power would be 10,300 by the old method and 9,000 by the new method, without any allowance for the roughness due to the plate butts, etc. It is not possible without experiments on a large scale to say which of these two methods is correct. Such an experiment was made on the "Greyhound," but unfortunately the experiment does not help us on this point. The vessel was comparatively short, being only 172.5 ft. in length, and for such a length, at the experiment speeds, both methods of calculation would give practically the

same frictional resistance. The actual resistance of the "Greyhound" exceeded that estimated by Mr. Froude by some 20 per cent (taken on the whole resistance), and whether this discrepancy was due to roughness of bottom, as suggested by Mr. Froude, or some other cause, it is too great to enable one to use the result as a check upon skin-friction data.

8. Passing now to assumption (3)—i. e., that the resisting quality of the ship's surface is the same as that of smooth planks—there can be little doubt that for all models all reasonably hard, smooth surfaces give the same result. W. Froude tested several ship compositions on planks and found this to be the case. Fig. 4 (below) gives the experimental spots for a 16-ft. model of 0.66 prismatic coefficient tested with four different surfaces, varnish, paraffin, fine red lead, black-lead, worked into the shellac, and these spots all plot on one curve. The tests made in the Washington Tank with 20-ft. plates 2 ft. deep showed practically the same resistance for shellac varnish and blacklead (the blacklead was laid on over the shellac and not worked into its



surface when it was just drying, as at the National Tank). Provided, therefore, that a ship had a wetted surface similar to that of an ordinary smooth model, this assumption would be perfectly correct. In a ship, however, the surface is always broken up by the heads of the rivets, and generally by the landings and butts of the plating. These must have some effect, and must cause any estimate based on the assumption of a smooth surface to be in error on the small side. This is dealt with in detail in 9 (c) and 10. It would appear from these considerations that the present method of extension of experimental data for short planks and bodies, although fairly accurate for short vessels of fine form, is subject to several errors when used for long ships. One of these—that due to assumption (2)—always tends to give an excess estimate for resistance, and the others—due to assumptions (1) and (3)—cause the estimate to be low.

THE FRICTION OF A ROUGH SURFACE

9. The data upon this have been increased very considerably in the last few years. Most of these data are derived from model experiments, but in some cases authentic data for ships are available. These data are given below in the order of the percentage effect produced by the particular roughness considered.

(a) One model of fine form, 16 ft. in length, tested in the National Tank, showed that plate edges increased the frictional resistance 3.7 per cent. The plates on the model represented 4-ft. strakes of $\frac{1}{4}$ -in. plating on a 400-ft. ship.

(b) A 20-ft. by 2-ft. plate, tested in the Washington Tank, "painted with light lubricating oil," at first showed an increase of resistance about 5 per cent over that of a varnish surface, but as the oil washed off the resistance excess decreased.

(c) Two models tested in the National Tank with plate edges and lapped butts (the laps of the plates being towards the stern) increased the resistance as shown in Table III. Model No. 1 was the fine form used for test (a) above, model No. 155 was full and broad, having 50 per cent of parallel body in its length (total length 15.3 ft.). The plates on the model represented 4-ft. strakes of $\frac{1}{4}$ -in. plating of 20 ft. length for a 400-ft. ship. It will be noticed that the effect of the removal of these laps and butts from the bow in the case of the full model was to reduce the resistance 3.2 per cent to 4.8 per cent. The variation in percentage effect with these landings and butts as speed is varied is probably due to the angular flow of the streams in the bow as wave-making shows itself. At the top speed there would be decidedly more flow across the plate edges than at the low speeds,

(d) One model (No. 1) tested in the National Tank with a very slight amount of fine grit mixed into a good smooth paint showed an increase in frictional resistance of 7 to 13 per cent.

(e) If the whole of the discrepancy between the actual resistance obtained with the "Greyhound" and that estimated by Mr. Froude be attributed wholly to roughness of the copper bottom, the increase in frictional resistance due to it amounts to 27 per cent.

(f) A large vessel lying at Newcastle for three months without docking showed an increase in its total resistance of 20 per cent, this being the result of measured-mile trials before and after the time-interval given.

(g) A 16-ft. by 2-ft. plate tested in the Washington Tank at speeds of 6 to 8.5 knots, with a surface coated with heavy cylinder oil, showed a resistance 48 per cent higher than that for a smooth surface. But the results indicated that at about 3 knots the resistance would be the same as for the smooth surface.

(h) A plate 20 ft. by 2 ft. tested in the Washington Tank after immersion in Chesapeake Bay for two months (July and August, 1914) showed an increase in resistance over that of a smooth surface of about 50 per cent. The fouling and resistance went on increasing up to the month of December, when the resistance stood at about 220 per cent increase over that for a smooth surface, and remained at that figure for some months. This suggests that a good time for cleaning and painting the bottom of coasting ships, working at about this latitude, is October and November, as there is little growth in cold water for the next few months. Presumably, there would be a period about May and June when the temperature had reached a point favorable for growth when a new coat of paint would prevent their adhesion to the surface.

(i) Tests in the Torquay Tank or planks 19 in. deep, of lengths 2, 8, 20 and 50 ft., covered with calico or fine sand, showed an excess resistance over that of smooth planks of the same length of 70 to 90 per cent for the 50-ft. lengths, and 100 per cent for the short lengths.

The same planks with medium or coarse sand had excess resistance of 125 and 175 per cent respectively for a short plank, 93 and 114 per cent respectively for a long one. The above examples of effect of rough surface have been limited in the case of full-sized ships to those for which the data have been seen by the author. Many other examples may be found in text-books on resistance.

10. In considering the model results, one important fact has to be borne in mind. It is essential for the correct application to ships of these results on small models that the roughness on the model shall be "similar" to that on the ship. Thus a 3-in. weed growth on a ship should be represented by a growth of about 0.15 in. on the model (the scale being assumed as $\frac{1}{20}$), not by the same sized growth. Tests with the latter will inevitably lead to a result largely in excess of the effect of the same fouling on a ship. Thus the coarse sand on the plank in case (h) would represent a fair growth of barnacles on a ship, and the calico test in the same example would represent about 1 ft. to 2 ft. weed on a ship. The plate-butts and edges in examples (a) and (b) were to scale, and their effect would therefore be the same on the ship as in the model.

11. The large increase in the ship resistance is not the only effect of a foul bottom. Large increase in the frictional resistance is bound to increase the wake to more or less the same extent. The result of this is that the screw is working at an unduly high slip, with a consequent drop in its efficiency, and this loss is additional to that due to the mere increase in resistance. The examples given show that there is every reason for believing that a ship experiences a large increase in its resistance when the wetted surface is roughened in any way, and, giving due weight to the statements in the previous paragraph, this increase will be about the same in the ship and in the model when both have "similar" rough surfaces.

Removal of Nicotine from Tobacco Smoke

It was found that many tobaccos yield a smoke containing large quantities of free nicotine, which can be extracted by passing the smoke through a cotton-wool plug treated with tannin. In some cases as much as 12.3 per cent of the total nicotine can be recovered in this way. It is suggested that the use of such plugs by smokers would be of advantage from a health point of view.—Note from the *Journal of the Society of Chemical Industry*.

⁴Trans. I. N. A., Vol. XXIX, page 304.

⁵On "The Law of Comparison for Surface Friction and Eddy-Making Resistance in Fluids." See *Engineering*, Vol. XXIII, page 428, 437.

Hardness and Hardening*

An Important Property Not Yet Satisfactorily Delimited

By Professor T. Turner, M.Sc., A.R.S.M., University of Birmingham

HARDNESS is a property which is of great importance in connection with the practical uses of metals. This is evidenced by the numerous methods which have been introduced from time to time for testing hardness, and also by the abundant literature which has been published on the subject. The latest contribution to this study is a "Report of the Hardness Test Research Committee of the Institution of Mechanical Engineers" (November, 1916), in connection with which a bibliography has been prepared. I have been privileged to assist in the preparation of this bibliography, which contains references to some 131 papers and other publications dealing with hardness and hardness tests. Even this list does not touch the question of hardening, which has been discussed by Sir George Beilby, Professor Edwards, Mr. McCance, the present writer, and many others. To the report above mentioned three appendices are attached, which give the views on the nature of hardness of Professor Unwin, Sir R. Hadfield, and Dr. Tutton respectively. From these appendices, which are of great interest, it is evident that the members of the committee, and those who took part in the discussion, are not agreed upon the fundamental conceptions as to the nature and definitions of that which they were endeavoring to measure.

Definitions and Measurement of Hardness.—It has been frequently stated that hardness is a property which cannot be measured or readily defined. This is merely another way of saying that we have not made up our minds as to what we mean by the term "hardness," for there is little difficulty in framing a definition when once a clear mental conception is reached. That which can be accurately defined is capable of measurement.

Though so eminent an authority as the late M. F. Osmond has used the word "measurement" in connection with hardness tests—see report *Sur la Dureté: sa définition et sa mesure*, Paris, 1892—physicists appear to have pretty generally expressed the view that hardness cannot be measured. Professor H. Le Chatelier, in discussing the "Report of the Hardness Test Research Committee" (page 777), admirably states this view as follows: "Two simple characteristics determined whether a quantity might be measured or not. If measurable, it should satisfy the laws of equivalence and accumulation. Temperature, though it followed the law of equivalence, did not follow that of accumulation. For instance, two bodies raised to the same temperature would not give a higher temperature if brought together. So that temperature could not be measured—all that could be done was to register it on certain scales. . . . Hardness was exactly the quantity which followed neither the law of equivalence nor that of accumulation."

It may be dangerous for one who can make no claim to be a physicist to differ from so recognized an authority as Professor Le Chatelier. On the other hand, it may be inconvenient to take words which have been familiar for centuries, and to endeavor to limit their application to the specialized uses of modern science. In the present instance it may be pointed out that a property is not necessarily a quantity; and it would scarcely be urged that hardness is a quantity in the sense of the physicist. Further, it may be remembered that the word "measure" has a much wider use in our language than is suggested by the laws of equivalence and accumulation.

What we require for practical purposes, is to be able to register hardness on a numerical scale, just as we do density, tenacity, viscosity, or other properties. For example, we determine relative density; it does not follow the law of accumulation, because if two bodies of the same density are brought together the density is not doubled—unless they are gases which can be compressed into half their original space. The determination is accurate, and similar results are obtained on repetition. Shall we say the density has been measured; or has it only been registered or determined? To the physicist the choice of a word here may be important. But the ordinary reader might be misled if he were told that the density, or the elastic limit, of a metal cannot be measured.

The definition which I myself prefer is that hardness is the property whereby a body is able to penetrate another body; and conversely, it is the property whereby a body resists being itself penetrated. This does not materially differ from the definition proposed by M. Osmond in 1892, that hardness is "resistance to permanent deformation." Sir Robert Hadfield's definition is simply "resistance to deformation." From the mechanical aspect, hardness, as so defined, will closely correspond with the "yield

point" or "breaking-down point," of the material. In ductile materials, such as relatively pure metals, of which mild steel is an example, the yield point is often roughly proportional to the ultimate tensile strength. In such cases the hardness, as measured by the stress per unit of area required to produce penetration, is less than, but varies with, the tenacity. In brittle materials the yield point and the ultimate strength are practically identical: in such cases tenacity and hardness will nearly coincide. The hardness may, however, exceed the tenacity, since in a tensile test the particles are drawn away or separated from each other, while in a penetration test there is a certain amount of "backing" in the material, which tends to support the penetrating body.

With penetration tests, such as those of Brinell, in which an appreciable quantity of metal is displaced, the true hardness is not obtained, since the displaced material becomes more or less work-hardened, and another similar test on the same spot will not give the same result. The difference may, however, not be large. In wearing tests the polishing, and consequent hardening, of the rubbing surfaces on the one hand, or their disintegration on the other, may lead to quite erroneous conclusions. Theoretically, the production of a scratch of standard width, and of indefinite thinness, with the employment of an ascertained weight, would appear to most nearly meet the ideal conception. For practical purposes the requirement of a smooth surface, and the difficulty of accurately deciding the character of the scratch, has prevented the extensive use of scratching tests by engineers, though such tests are still preferred by mineralogists and other workers. The conception underlying the Brinell test is a simple one—namely, that a unit of surface will just maintain a stated pressure before being deformed. So long as the amount of deformation of the sample is not excessive, and provided the body to be tested is not brittle, the Brinell hardness number closely corresponds with true physical hardness.

Resistance to Wear.—For many purposes, however, the engineer does not really require hardness, though he asks for it. What he does desire is resistance to wear, or to deformation, or some other property or combination of properties which are of importance for the particular purpose he has in view. Thus, if we consider a wearing or grinding test, it is necessary, if the metal is not to wear away quickly, (1) that the particles on the surface shall not be readily displaced, and (2) that the particles so displaced shall not be readily removed. Both conditions are necessary; either alone is not sufficient. Substances which are really hard do not permit of their particles being readily displaced—hence they wear well. Plastic metals do not permit of their displaced particles being readily removed—hence they, too, may give good wearing surfaces, though they are really very soft. The wearing properties of manganese steel, for instance, would appear to be due to two causes: (1) The relatively high natural hardness of the material itself; (2) the fact that the particles which are displaced from the surface do not come away and form a powder, but are plastically spread over other parts of the surface; they are thus capable of being repeatedly displaced, and are work-hardened before being ultimately lost.

A number of unfortunate terms have been introduced during the last few years, such as "tensile hardness," "wearing hardness," "elastic hardness," and so forth. These terms are misnomers. Thus tensile hardness is merely tenacity; but tenacity indirectly measured by some apparatus which is found to give results which, when multiplied by a suitable factor, are approximately the same as those obtained by the tensile testing machine. This term has been almost exclusively used in connection with tests of mild steel, such as is used for constructional purposes and for somewhat harder material as employed for rails. In such cases, as has been already pointed out, the true hardness is less than, though approximately proportional to, the ultimate tensile strength.

Hardness of Pure Metals.—If attention were confined to the pure metals in their cast, annealed, or unwrought condition, the question would be much simplified, for the hardness varies inversely as the atomic volume. In other words, the hardness increases as the number of atoms in a unit space increases. Mr. S. W. Smith has also shown that with liquid metals surface tension varies inversely as some function of the atomic volume, while Dr. F. C. Thompson suggests that the elastic limit is dependent upon surface tension. Dr. Tutton has shown that with

a number of substances other than metals, the hardness varies as the molecular volume, provided always that similar materials are compared. Dr. Tutton has also pointed out that it may be anticipated in crystallized substances, owing to the arrangement of atoms in the crystals, there may be some differences of hardness in different directions in the same crystal.

It is frequently stated that pure metals are not to be obtained commercially; but it is worthy of remark how exceedingly pure some commercial samples of metal really are. Thus lead, tin, and zinc are sold by the ton with an analysis which shows 99.95 per cent of the respective metal, and only one part in two thousand of total impurity. But for the majority of purposes pure metals are too soft, and must be hardened in some way.

Methods of Hardening.—There are three methods whereby the hardness of a pure metal may be increased: (1) by alloying; (2) by cold working; (3) by chilling.

Chilling may be regarded as a combination or variation of the first two methods. It may lead to the setting up of internal strains, which really produce the effect of cold work; or it may change the chemical composition of an alloy by causing some constituent to remain in solution, or even prevent a constituent from going into solution. The hardening of steel, and the softening of certain bronzes, by chilling, are examples of this effect on internal composition. Ultimately, therefore, metals or alloys can only be hardened by a change of composition or by strain.

When we add to one metal another metal, or other element, and allow the product to solidify, the result is a mixture, a compound, an eutectic, or a solid solution. The useful ductile alloys are, almost without exception, solid solutions. Since this fact has been recognized, special attention has been given to the nature and properties of metallic solid solutions, and some important generalizations are now fairly well known.

Hardness of Solid Solution.—As we pass from either end of a series of solid solutions towards the center of the series it will be found that the hardness, the limit of elasticity, and the tensile strength increase, but the ductility—as measured by the extension and the reduction of area—and the electrical conductivity decrease. The melting point usually changes fairly regularly throughout the series. These facts for a series of solid solutions of a metal A, and any other metal, metallic compound, or non-metal B, which forms a series of solid solutions with the metal A, may be diagrammatically represented in the simplest possible manner, as in Fig. 1.

If a series of solid solutions be interrupted by the presence of compounds, or of eutectics, these will be indicated by irregularities in the hardness and other physical properties, at such points as correspond with the end of the series in the respective cases.

It will thus be seen that it is possible to harden either constituent by addition of moderate proportions of the other. At the same time the material becomes less ductile—in other words, more brittle. A point is frequently reached at which the tenacity can no longer be increased with safety, owing to the continued increase in brittleness. But the metals we add do not necessarily diminish the ductility in their alloys at the same rate as they increase the tensile strength. For example, nickel, copper, manganese, or chromium may be added to steel in such proportions that the improvement in tenacity is much greater than the deterioration in ductility. Hence the application of such metals, in suitable proportions, in steels for special purposes.

In the copper alloys the same general principles are adopted. The proportion of zinc which can be added to copper, in order to strengthen it, is limited by the loss of ductility, having regard to the purpose in view. For ductile bronzes, as is well known, the limit of zinc is usually about 30 per cent. Small quantities of iron or of manganese may increase the tenacity more rapidly than they deteriorate the ductility. Of this we have examples in the manganese and iron bronzes.

It is stated in the "Ninth Report of the Alloys Research Committee"—page 133—that the effect of adding manganese to an alloy of copper and aluminium was to raise its yield and tensile strength without reducing its ductility to a corresponding extent. With increased knowledge of the effects produced by relatively small additions of the less common metals to our alloys, it is

*Institute of Metals, September, 1917. Reported in *The Engineer*.

Journal of the Institute of Metals, No. 2, 1914, Vol. XII, page 206.

*See Kurnakow and Shmentchusky, *Journal of the Russian Physical Chemical Society*, 1908, Vol. XI, page 1067, also Dr. Desch, "The Hardness of Solid Solutions," *Paraday Society Discussion*, 1914, page 46.

probable that a useful field will be opened for increasing their hardness without producing brittleness.³

Hardening by Cold Work.—Turning now to the hardening of metals by cold working, it is well known, to those interested in the wrought metal industries, that the effect of such processes upon the mechanical properties of many metals and alloys is remarkable. The yield point and tensile strength are raised, while the elongation and reduction in area—or ductility—are markedly lowered. The electrical conductivity is only slightly affected. Further work put upon the metal causes it to fracture. By suitable annealing the material may be rendered soft and ductile as before. The material in its wrought state not only has greater strength, but is also harder than the original metal or alloy. But when that hardness is measured by different instruments, such as the sclerometer, the scleroscope, or the Brinell tester, it is not found that the values obtained are in agreement. Hence the hardness produced by cold working is different in kind from that resulting from the alloying we have previously discussed.

It might, perhaps, be assumed that rolling, hammering, or pressing a metal would render it more dense, and that the observed increase of hardness is due to such added density. But any change of density due to mechanical processes is far too small to permit of being explained on the principle of atomic volume. Further, as a matter of fact, the change is ultimately in the opposite direction. The first result of pressure is to close up any pores, cracks, or blow-holes, and thus to increase the apparent density; hence bars are usually more dense than the ingots from which they have been rolled. The subsequent effect of cold working is to slightly but appreciably diminish the relative density of the worked material. It is important to consider how this change is brought about.

If a piece of metal be stressed to any extent below its elastic limit, and the stress is removed, the metal returns to its original form and volume, and no hardening results. But if the stress be increased, so that the elastic limit is passed, permanent stretching or strain results, and the metal becomes worked hard. This stretching or deformation occurs, as has been shown by Rosenhain and other workers, chiefly, if not entirely, by shearing slip along planes of internal crystal symmetry. It matters not whether the force be applied in the form of a pull of a tensile machine, a blow as from a hammer, or pressure as in a compression test; there is no hardening unless there has been shearing flow, and this flow generally, if not universally, results in a small but appreciable diminution of density.⁴ We may profitably inquire how this change of density originates.

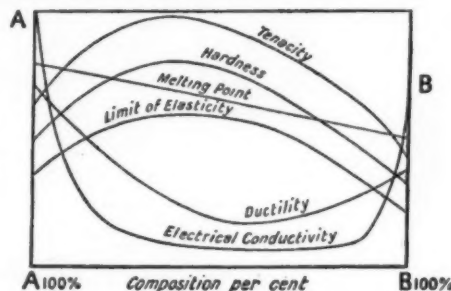
Cause of Work Hardness.—If we imagine a solid crystal which is under strain, as a result of which shear occurs along a plane of crystal symmetry, it will be evident that at the moment the particles are pushed asunder and caused to slide upon each other, they were clinging to each other, and were separated only with difficulty, and by what we usually call a "pull" of sufficient strength. The materials thus clinging to each other, and forcibly separated, were in a state of tension. It would, therefore, appear that the intervening layer of "amorphous" material cannot be in a normal or unstrained condition, neither can it be in compression; it must, therefore, be in a state of tension. When a bar of metal is in tension it becomes longer, and the extension is proportional to the stress applied. But in such a case the bar becomes thinner as it elongates; so the extension must not be regarded as indicating any volume change. Yet doubtless there is a small, but nevertheless real, volume change when a bar is stretched or compressed. It is just as real as the expansion of a gas on reducing the pressure, though almost indefinitely smaller in amount. It is this volume change, due to tension, which leads to the observed diminution of density in wrought metals.

That diminution of density does result from cold working has been shown experimentally by many observers. Thus Brunton found that in drawing steel wire its specific gravity could be increased from 7.768 to 7.998 by cold work, but that when this point was reached further drawing caused the density to decrease. Kahlbaum has shown that the density of platinum wire is reduced from 21.43 to 21.41 by wire drawing. Lowry and Parker found that metallic filings are in a worked hard condition, and that by annealing their density increased. Professor Lee, of Birmingham, has found that the density of mild steel is diminished if it be subjected to compressive stress which leads to distortion. Lastly, it may be recalled that Professor Heyn, in his May Lecture,⁵ has proved that in

cold-rolled bars the outside is in tension and the inside in compression.

Hardness and Tension.—When steel, which contains carbon, is hardened by means of rapid cooling, it is well known that the density of the hard steel is less than that of the soft or annealed material. Hence Professor J. W. Langley suggested the hypothesis that hardness corresponds with a condition of internal tension, and softness with the absence of tension. H. E. Field,⁶ a little later, suggested that the hardening of iron is due to the particles being forced and held farther and farther apart, whether by heat or mechanical means. W. Metcalf, in discussing Field's paper, stated that cold working reduces specific gravity, while it increases the hardness, tensile, transverse and torsional strength. He has also proved by actual measurement and weighing, on a commercial scale, that the density of cold-rolled wrought iron bar was less than that of the original metal.

These tests were conducted at Messrs. Jones and Laughlin's works when Mr. Metcalf was acting as assistant to Major W. Wade. Specific gravity tests showed that the cold-rolled iron was less dense than the hot-rolled bars. Major Wade was so surprised with the results that he arranged for a number of samples to be weighed, without vouchsafing any reason. Mr. Metcalf's results agreed with those of Major Wade, but they were so contrary to what was then the general theory that further tests were made. Hot-rolled bars were pickled, cleaned, carefully measured, and the cubic contents calculated. They were then cold rolled and carefully measured, when it was found that the increase of length more than compensated for the reduction in diameter. Many similar examples could readily be found.



Films in Tension.—The conception of stretched layers existing between the particles of a cold worked metal, or at the surface of a polished metal, has led various thinkers and especially our President, Sir George Beilby, to recognize the similarity which must exist between such layers, and the surface tension with which we are familiar in liquids. This surface tension leads to the formation of so strong a skin upon water that a fly can walk upon it, or a greased needle float. But it would be unwise to assume, because there are some obvious similarities, that, therefore, all the laws which are applicable in the one case are equally true in the other.

It is evident that if a membrane is to be stretched there must be some body to which it can be attached, or to which it can adhere. The head of a drum is an illustration of this fact. In the case of a liquid drop the skin extends all around; but in other instances the film support is supplied by the sides of the containing vessel. It is interesting to inquire how the planes can remain stretched in a solid body, such as a cold worked metal.

If we could imagine the extreme case of the whole of the crystalline material being converted into the amorphous state, and all the planes being parallel to the length of the body, we should have an impossible condition, since all the layers would be in extension, with nothing to keep them extended. This could only exist with a body acting under external tensile stress. Such a body would be incapable of shearing strain; its yield point and its ultimate stress would coincide; it would be brittle like glass. Glass is brittle because there are no planes of shear. But in the case of a metal or alloy consisting of mixed crystals, differently oriented, strain leads to the production of a series of slip planes in each crystal aggregate. Adjoining areas, as viewed in a microscopic section, have their planes at various angles to each other, owing to the different arrangement of the component microcrystals in each crystal aggregate. These planes, or thin films of amorphous material, may be regarded as being held in tension either by the rigidity of the crystal envelope—or cement—or by the mass of the unchanged material, or by both of these. But in ordinary mechanical processes, such as rolling, hammering, or drawing, we have not to deal with a single deformation, and one set of shearing planes in each crystal grain. Deformation follows deformation, and planes are set up in many directions. These slip planes cross and recross each other, their direction being limited only by the necessities

of crystal symmetry. A section thus shows a network of crossing lines, each of which we assume to correspond with an extremely thin layer in tension. We have in such a section an intricate network, which is held together by tightly stretched strings or tapes, and supported by intervening, unaltered crystalline material. When we remember the great strength of a lattice girder, or of woven wire, we can more readily understand how these extremely thin layers of amorphous material, all of which are in tension, are able to confer great tenacity and hardness upon a worked ductile metal. The fact, referred to by Rosenhain, that metal which has been hardened against tension is softened against compression, is entirely in harmony with the foregoing explanation. But since the whole of the crystalline material never is, and never can be, completely converted into the amorphous condition, it follows that there must be unequal hardness and unequal tenacity throughout the various portions of the worked hard material.

Herein lies the essential difference in the character of the added hardness which is conferred by alloying and by cold working respectively. In the case of alloying we deal as a rule with a solid solution, which as a result of osmotic pressure is in a state of molecular tension, and every unit of which is of similar composition. It is true that with castings "coreing" occurs, but that does not really affect the argument. With a solid solution various methods of testing hardness should give results which are in general agreement. Worked hard metals, on the other hand, are less uniform in hardness, and if tested in various ways may give different results, depending upon the character of test selected.

Limits of Work Hardening.—It may be of interest to consider to what extent a metal may be hardened, or have its tenacity increased, as a result of cold working. It is difficult to suppose that any means could be found whereby the tenacity of a film of metal could be made to exceed the tenacity of a thin polished film at the surface—that is to say, to exceed the surface tension. Now Quincke calculated the capillarity constant of certain solid metals and alloys, or, in other words, the pull exerted upon one millimeter of surface. With iron, silver and gold the ratios of the hard to the annealed state were about 3 or 4 to 1. With certain alloys it was less than 2. With steel it was about 7 to 1. These values must be regarded as rough approximations, and merely indicate the kind of numbers with which we have to deal. What they do show is that even if the whole of a sample of metal could be converted into material having the properties of a surface film, there is a definite limit to the hardness which could be imparted by the processes of cold working. In other words, after a certain point had been reached further work would not confer greater hardness, but would cause fracture.

But if it be true, as before suggested, that it is impossible to convert the whole of any metal into thin films, in a parallel direction, then it would follow that the attainable limit for increased hardness is below the figures which have been previously mentioned. In practice, for example, cast copper has a tenacity of from about 10 to 14 tons per square inch. When it has been drawn as far as is mechanically possible, in view of the purposes to which it is to be applied, its tenacity is from about 24 to 28 tons. Roughly, therefore, its tenacity has been doubled. In some cases less than this is possible; in exceptional cases more can be obtained. But always the maximum is only a small multiple of the original.

Even if we had information as to the proportion of the mass which had been converted in stretched films, it would not appear possible to calculate what the increased hardness or tenacity should be, and so check it by experiment. For if we accept the view that these planes are like so many strong bands passing through the material; that they are of varying length, and crossing and interlocking with each other at an indefinite variety of angles, it will be seen that we are dealing with a system of astonishing complexity which none of the usual methods of examining stresses would be able to unravel.

In a recent paper by P. Ludwik,⁷ of which I have only as yet seen an abstract, the view is expressed that the phenomena of cold working are not explicable by Sir George Beilby's amorphous hypothesis, or by Tamman's translation hypothesis. Ludwik draws attention to the fact, which had already been stated by Professor H. M. Howe, and carefully studied by Matthewson, that the greater the amount of mechanical work the lower is the temperature at which softening takes place on annealing. In the foregoing remarks I have endeavored to show that if it be assumed that the amorphous material exists in the condition of thin films, in tension, akin to surface films of liquids, then the results of cold working can be readily understood. And it would appear to follow that the more numerous these films are, and the more they are strained, the more readily will they tend to adjust themselves as the temperature is raised.

⁷International Journal of Metallography, 1916, Vol. VIII, p. 53.

³P. Ludwik has recently published a research dealing with the hardness of a large number of alloys—Abstract, The Ironmonger, April 7th, 1917.

⁴I understand that when coinage blanks are pressed there is an increase of density. If this is so it must be regarded as a special case, as the specimen is practically in a closed box and is not free to expand.

⁵Journal of the Institute of Metals, No. 2, 1914, Vol. XII, page 14.

⁶Bulletin of the American Institute of Mining Engineers, 1903, page 571.

NEW BOOKS, ETC.

THE MASTERY OF NERVOUSNESS, by Robert S. Carroll, M. D., New York, 1917. The Macmillan Company, 12 mo. 346 pp. Price \$2.00.

The man or woman, suffering from nervous debility, will find this book an ever-ready, practical help in the way back to health. Dr. Carroll gives in simple, fluent language, apt in expression, the causes of nervousness, its relation to contemporary conditions of living and efficient methods to overcome it. The physician who recommends this work to his patient will find it a valuable assistant to supplement his treatment. This is a particularly valuable book, for the problem that the modern man is facing today for himself and his children and which is becoming more complicated each decade.

SCIENCE AND LEARNING IN FRANCE. With a Survey of Opportunities for American Students in French Universities. An Appreciation by American Scholars. Published by The Society for American Fellowships in French Universities, 1917. 8vo.; 492 pp.; illustrated.

It is well indeed at this time, when the United States and France are fighting side by side for common principles, that we should know the full extent of our indebtedness to each other. Most of us have vague ideas of what France has given to the world in scientific knowledge and research; our representative American scholars have in this series of papers definitely set forth, for each particular field, the great leaders and the achievements of the past century, the courses of instruction offered by French universities, and the general facilities available for study and research. From anthropology to zoology each subject is handled by two or more men qualified to speak with authority; John Dewey of Columbia University is one of the four notables responsible for the section on education; Charles W. Eliot of Harvard and George E. Hale, foreign secretary of the National Academy of Sciences, give us introductions dealing with the mind of France and the intellectual inspiration of Paris. Our visiting students will be greatly aided by the information of the appendix, which explains the organization, the standards of preparation and system of degrees of the French universities. The section on medicine is particularly thorough, including physiology, neurology, surgery and pathology.

LOCOMOTIVE VALVES AND VALVE GEARS. With a Special Treatise on Valve Setting. By Jacob H. Yoder, B.S., M.E., and George B. Wharen, B.S., M.E. New York: D. Van Nostrand Company, 1917. 8vo.; 286 pp.; illustrated. Price, \$3 net.

Valve setting presupposes a knowledge of the principles of valve motion, and this is a subject on which the initiated are apt to be a little cryptic; the railroad shop man on a voyage of mental discovery is likely here to run into mist and mystery. This commendable work, based upon notes used in the apprentice schools of the Pennsylvania Railroad, is an exposition that dispels the fog and gives the facts in simple English. The plain slide valve, piston valve, and operating gears are taken up from the points of view of construction and action, and their application to the locomotive is made plain to the everyday worker. The engineman and fireman, the draftsman and the designing engineer may also use the work to advantage as a reference book of practical information.

THE AMERICAN FERTILIZER HAND BOOK. 1917. Philadelphia: Ware Bros. Company. Price, \$1.

It was no easy task which faced the compilers of this year's issue of the Hand Book; the war had created a condition which made it difficult to include anything like complete statistics, yet the intimate relationship of the commercial fertilizer to the food supply, and of the food supply to the successful prosecution of the war, gives added importance to a work dealing with commercial fertilizers and offering directories of fertilizer manufacturers and allied trades; the result is a triumph for the compilers worthy of the highest praise. Their work is also a guide to materials, machinery, and all kinds of equipment and supplies; to brokers and shippers; to chemists, assayers, engineers and contractors; to cotton seed oil mills and to packers and renderers. These directories have been subjected to the most careful revision, and the trade can readily obtain from them exact information as to sources of supply for plant equipment, raw materials and expert service.

THE MAGIC OF SCIENCE. By A. Frederick Collins. New York and Chicago: Fleming H. Revell Company, 1917. 12mo.; 215 pp.; illustrated. Price, \$1.25 net.

The author has mastered the art of writing for boys in such manner as to convey instruction by means of recreation; his latest work is full of fascinating experiments capable of being performed with the aid of simple, home-made apparatus and toys, yet highly educational in that they initiate the young experimenter into the mysteries of matter, force, and mechanical principles. Natural magic is thus made interesting to the normal boy, a new world dawns upon his intelligence, and he learns to take the keenest pleasure in tracing effect to cause. There are a few mistakes such as reference in the text to non-

existent letters in the illustrations, but these are in no case serious; the line drawings are very attractive and make it easy to follow the directions and explanations.

WHITE'S VEST POCKET SUNDAY FORMULARY. By E. F. White. Boston: The Spatulary Publishing Co., 1917. 200 pp.; illustrated. Price, \$1.

The soda-fountain dispenser will welcome this handy little formulary, which provides him with a new frozen confection for every day for four years, or a new "special" every week for twenty-five years; in other words there are 1,200 different sundae and 300 dressings here mentioned, enabling the dispenser to prepare, with a glance at the concise instructions, any sundae a customer is at all likely to ask for.

THE LIFE OF ROBERT HARE. An American Chemist (1781-1858). By Edgar Fahs Smith, Provost of the University of Pennsylvania. Philadelphia: J. B. Lippincott Company, 1917. 8vo.; 608 pp.; illustrated. Price, \$5 net.

When a man is called before a learned society at the age of 21 to demonstrate his discovery of the oxyhydrogen blowpipe, and when that man's passion for research carries him through all difficulties until the publications of the day herald him as "the greatest American light of chemical science" and the peer of Sir Humphrey Davy and Volta—then we have a character that must present splendid material for an inspiring biography. This fascinating volume tells the story of Robert Hare's struggles and triumphs, with the view of making the public better acquainted with the strong personality and the epoch-making achievements of one of America's most eminent pioneers in science. The author comes to his subject with a steady enthusiasm that gives us an intimate and sympathetic delineation of the great thinker and experimenter. The frontispiece is a fine portrait of the chemist and physicist, reproduced from an oil painting in possession of the University of Pennsylvania.

THE YACHTSMAN'S ANNUAL GUIDE AND NAUTICAL CALENDAR. 1917. Boston: Clarence B. Hogg. 8vo.; 392 pp.; illustrated. Price, paper, \$1; cotton duck, \$2.

An encyclopedia of nautical information and instruction is offered the yachtsman each year in this old, reliable Guide. There are a dozen large charts of the principal harbors, one of Long Island Sound, and one of the Cape Cod Canal. Besides the usual miscellany of racing rules, signaling codes, tide tables and water routes, there are four new pages on New York State and Canadian canals; sailing directions, distances and harbors on the Great Lakes; and many other additions and revisions. Other valuable sections are those on the operation of motors, weather signs, life-saving and power boat regulations; and the directory and flag index of American and Canadian clubs, showing the flags in colors, is a valuable feature of the Guide.

LAWS OF PHYSICAL SCIENCE. By Edwin F. Northrup, Ph.D. Philadelphia: J. B. Lippincott Company, 1917. 12mo.; 210 pp. Price, \$2 net.

The author has here given us an epitome of the fundamentals of science, a full list of its general propositions or laws. The value of such a list as a work of reference is obvious, and will appeal to students in all branches of natural science. The subject-matter includes mechanics; hydrostatics, hydrodynamics and capillarity; sound; heat and physical chemistry; electricity and magnetism; and light. There are frequent references to standard text-books of the various subjects and a good bibliography is appended.

LIFE AT THE U. S. NAVAL ACADEMY. The Making of the American Naval Officer. By Ralph Earle, Commander, U. S. Navy, Head of the Department of Ordnance and Gunnery, United States Naval Academy. With an Introduction by Franklin D. Roosevelt, Assistant Secretary of the Navy. New York: G. P. Putnam's Sons, 1917. 8vo.; 380 pp.; 73 illustrations and map. Price, \$2 net.

How few of us realize what must be packed into the four-year course of the Naval Academy! In 48 months, as the Assistant Secretary of the Navy points out in his admirable introduction, high school graduates are fashioned into "not only educated gentlemen, but also international lawyers, keen observers, navigators, artillerymen, engineers and also all around men and specialists." Commander Ralph Earle tells exactly how this miracle is accomplished and throws open to the reader the whole educational, moral and recreational life of the Academy; the mental and physical requirements of the candidate are helpfully set forth; the settling down of the raw midshipman into routine is described; we are carried through the interesting life of the officer in embryo until the study and drill culminate in the final examinations, and the midshipman becomes that proud product of wisdom and discipline—the ensign. An appendix gives the courses of study in the post-graduate department, and there is a folding plan of the Academy Reservations. Not only the prospective candidate, but every American boy and man might profit by learning from this well-written volume what America expects of her naval officers, and what she owes to their indefatigable labors as humble midshipmen.

MR. BRITLING SEES IT THROUGH. By H. G. Wells. New York: The Macmillan Company, 1917. 8vo.; 443 pp.; illustrated. Price, \$1.00.

Inasmuch as the individual can typify the nation, Mr. Britling embodies the soul of England. We live the happy life of Matching's Easy, make the acquaintance of Mr. Britling and his unconventional family, and play Homeric hockey oblivious to the gathering clouds; seldom has Mr. Wells been so felicitous in his humor as here; it is delicious. Then the storm breaks; the young and lovable German tutor leaves to fight for his country. "Verdammt Dummheit!" is his comment on the situation. England is involved in the monstrous war; there is bewilderment, incredulity; the Zeppelins appear, and realization and rage arrive with them. From the point where the son of the house enlists, the narrative takes mainly the form of Mr. Britling's musings; the readjustments of his mind correspond to the readjustments of national life, and reflect the "web of the ineffective" in which England struggles. Mr. Britling loses his son, and finds his mental conceptions plunged into chaos; the book leaves him as he begins to regain a sense of beneficent purpose behind it all. Aside from the high literary value of the work it is one that all Americans should read, for it will give us sympathy and understanding for our allies and may educate us into avoiding some of the errors into which they fell.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES. New York: S. E. Hendricks' Co., 1917. 4to.; 2,227 pp. Price, \$10.

It would be hard indeed to lay too great a stress on the value of this massive collection of industrial and mercantile information, or on the sterling service it renders to the business world. The amplitude of its offering leaves little to be desired, and anyone interested, either as buyer or seller, in any kind of building construction and equipment, or in railroad, mining, or engineering materials, will find that this widely-used directory gives ready access to the sources of supply and demand. It furnishes three very complete, correlative lists, one of trades classified, another of trade names, brands, etc., and a third containing the names of all firms and individuals appearing in the classified-trades section, arranged alphabetically, with particulars of their chief activities and other specific and helpful items of information not generally found in less comprehensive publications, yet necessary to the expeditious and economical procuring of supplies. The method used in obtaining these details is the only one that ensures fullness and accuracy in compilations of this kind; that is, direct appeal to the firms listed, and the brief embodiment of the data thus acquired under the proper classification, thus making the whole work authoritative. Two indexes, one to classifications, the other to advertisers, greatly facilitate reference. The third section of the volume constitutes a new feature that offers such appreciable advantages that it will doubtless be retained in future editions. The trades and professions to which the register especially caters must accord it a grateful reception; indeed, there are few branches of industrial activity that would not be materially advantaged by its constant use in their purchasing and selling departments.

FRENCH MEASURE AND ENGLISH EQUIVALENTS. By John Brook. New York: Spon & Chamberlain, 1917. Price, 40 cents.

THE BAROMETRICAL DETERMINATION OF HEIGHTS. By F. J. B. Cordeiro. New York: Spon & Chamberlain, 1917. Price, 50 cents.

Merchants, manufacturers, engineers and others will welcome Mr. Brook's compilation, which will fit the vest pocket and contains the English equivalents of French measures both in decimals and fractions; the decimals are carried to six places. It includes also the French Old System, still occasionally used in connection with tool steel and files, and some Prussian, Austrian and Russian equivalents. Mr. Cordeiro's little work presents a practical method of barometrical leveling and hypsometry for the benefit of surveyors and mountaineers, with methods and formulas that, unlike the older ones, give accurate and consistent results. The work is in its second edition; when it becomes generally known to mountain climbers the annoying discrepancies now noted in their findings, and due either to false assumptions or to failure in including all the conditions of the problem, will disappear.

PRACTICAL BANKING. By O. Howard Wolfe, Assistant Cashier, The Philadelphia National Bank. Chicago: La Salle Extension University, 1917. 8vo.; 302 pp.; illustrated. Price, \$2.00 net.

Banking is of course only to be mastered by entering a bank, and by tracing the channels of its varied activities from beginning to end; but there can be no doubt of the benefit a student may derive from a work such as Mr. Wolfe here gives us. The business man, less excusably, is often woefully ignorant of inside banking methods, and to such a one the work should come as a welcome revelation. It is the commercial institution, in its functions of deposit, discount and issue, to which the exposition is mainly devoted, and it thoroughly canvasses the duties and systems of the executives, the tellers, and the bookkeepers. Under the subject of sight drafts

(Chapter II), there is a rather bewildering statement that the deposit of a hundred drafts causes the bank 600 times more work than the deposit of one draft; and the review question concerning issue does not seem to be elucidated by anything in the chapter. On the whole, however, the book will fill a distinct need, and is characterized by illuminating simplicity of statement.

PELOUBET'S SELECT NOTES ON THE INTERNATIONAL SUNDAY SCHOOL LESSONS. 1918. By Rev. F. N. Peloubet, D.D., and Amos R. Wells, Litt.D., LL.D. Boston: W. A. Wilde Company. 8vo., 372 pp.; illustrated. Price, \$1.25 net.

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Charles Allen Munn, President
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The Scientific American Publications

Scientific American Supplement (established 1876).....per year \$5.00
Scientific American (established 1845)....." " 4.00
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